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COST-EFFECTIVENESS METHODOLOGY FOR EVALUATING KOREAN INTERNATIONAL COMMUNICATION SYSTEM ALTERNATIVES

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ABSTRACT

Cost and Effectiveness models are developed by using of cost-effectiveness technique for fiber optic cable and satellite communication media. The models are applied to the Korean international communication problem. Alternative selection is required since the two medias different in cost and effectiveness. The major difficulties encountered were data gathering and measuring the effectiveness of the Korean international network. The research recommends the use of a cost-effectiveness methodology and suggests are provided for future Korean communications.

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I. INTRODUCTION

A. BACKGROUND

The communication system of Korea has a 100-year history, the modern postal system having been introduced in 1884 and the first telegraph service in 1885. The whole development process of the country's communications may be divided into three stages: the first 76 years from 1885 to 1961 may be termed as the period of stagnation;the following 20 years from 1962 to 1981 as the period of planned development for modernization of communication facilities; and the next five years from 1982 as the period of the intensified development plan in preparation for the emergence of the information society. The period of stagnation was characterized by negligible progress in communication development due to the World War and the Korean War. Communication facilities in Korea underwent remarkable progress during the period of planned development. Five consecutive five-year communications development plans began in 1962, in parallel with the national economic development plans. Communications development was regarded as part of national economic development. The first five-year plan(1962-1966) was to secure basic communication facilities. The second plan(1967-1971) was to expand international and long distance transmission lines. Long distance transmission lines were remarkably improved by the completion of the microwave network in 1967 and the coaxial network in 1969, and a satellite communication earth station set up in 1970. The objective of the third plan(1972-1976) was to expand and improve rural communication networks so as to ensure the balanced development of urban and rural areas. The major aim of the fourth plan(1977-1981) was to lay the foundation for the expansion of communication facilities. During this period, the second satellite communication earth station and a submarine cable link between Korea and Japan were put into operation with a view to expanding international communication facilities. The period of the fifth plan(1982-1986) is devoted to a massive expansion of the communication networks to meet the demand for telephones, and to improve the rural communication network. Digitization of transmission lines is also under way. The administration is in the process of replacing existing long-distance transmission lines with digital microwave

systems. Government has a investment plan for fiber optic transpacific cable construction in 1988 [Ref. 1: p. 5], and is about to start construction of a domestic network. With this historical version of Korea's communication development, the capacity of the communication systems has steadily increased with economic development. However, Korea still needs to expand or change its long-distance transmission media in a view of international technology development trends. Korea relies on leased satellite, coaxial cable and microwave systems for long-distance network. Since the fiber optic technology is developing rapidly, its influence on other communication systems are strong in terms of cost and effectiveness. Therefore the present long-distance system should be reconsidered by decision maker or planners.

B. PROBLEM STATEMENT

There are two basic options for upgrading long-distance transmission media:fiber optic cables and satellites. The problem is which option or mix of options would be better if the decision is made now. The decision problem between fiber optic cable and satellite systems are a growing issue in Korea. Since the internationally connected network should link to the domestic area, the two basic options would lead to different alternatives. So then, how does one make a choice? What methodology should be used to help the decision maker? There are several methodologies that could be used: breakeven analysis, payback period, the various rates of return such as internal rate(IR), external rate(ER), return on investment (ROI), and cost-benefit ratio. The above described methodologies mainly deal with the exact amount of money, output, profit or benefit in terms of dollar value. In contrast, cost-effectiveness methodology begins with the premise that some identified program outputs are useful, and proceeds to explore how these may be most efficiently achieved, or what are the costs of achieving various levels of the prespecified output. Furthermore, it is sometimes impossible to evaluate the benefits in dollar terms. This is particurally true in public sector decision making.

C. OBJECTIVES

The overall objective of this thesis is to develop a cost-effectiveness(CE) methodology to aid decision makers in selecting an international public communication system. The specific sub-objectives are as follows:

- To develop relevant cost models for fiber optic and satellite systems. The models will be developed assuming an "off-the-shelf" technology will used. Hence R&D costs may be neglected.
- To develop relevant effectiveness evaluation models by adapting existing evaluation models found in the literature. Existing models are for military cases(TRI-TAC), but civilian models could be developed by adapting the main concepts.
- To integrate the cost and effectiveness models into a useful cost-effectiveness methodology.
- To demonstrate the methodology by application to the Korea communication system selection problem.

II. REVIEW OF COST-EFFECTIVENESS ANALYSIS

A. CONCEPT

Cost-effectiveness is a measure of effectiveness of systems in relationship to their cost. Cost-effectiveness is an old concept. It was first given impetus as a formal engineering discipline by Arthur M. Wellington in his classic treatise, "The Economic Theory of Railway Location", as long ago as 1887 [Ref. 2: p. 2]. In 1923, J.C.L Fish of Stanford probably was the first to write a book exclusively devoted to engineering economy. In the 1930's and 1940's Eugene Grant, also of Stanford, brought about widespread awareness on the part of engineers of the need for economic evaluation of engineering projects. Great impetus was given to the need for economic evaluation of systems by Charles Hitch and R.Mckean. Their book "The Economics of Defense in the Nuclear Age", set the stage[Ref 3]. As Assistant Secretary of Defence(comptroller) Charles Hitch was in a position to bring about a realization of the need for the proper economic evaluation of defense systems The basic idea of cost-effectiveness analysis is a type of systematic study which is "designed to assist a decision maker in identifying a preferred choice among possible alternatives". It is worth noting that the emphasis is placed on establishing a basis for making decisions. While the above authors were concerned mainly with defense systems the generality of the methodology which they discussed is valid for the design of any system. In the 1970's the emphasis on cost-effectiveness became focused on the need for making decisions based on the life-cycle cost. Cost-effectiveness in its modern use is concerned with estimation of costs and the evaluation of the worth or effectiveness of systems.

B. COST

1. Cost Structure

The cost structure is used as a basis for assessing the life-cycle cost of each alternative being considered. The cost structure(or cost breakdown structure) links objectives and activities with resources, and constitutes a logical subdivision of cost by functional activity area, major element of system, and/or one or more discrete classes

of common or like items. The cost structure, which is usually adapted or tailored to meet the needs of each individual program, should exhibit the following characteristics:

- All life-cycle costs should be considered and identified in the cost structure. This includes Research and Development(R&D) cost, Production cost, and Operation and Support(O&S) cost.
- Cost categories are generally identified with a significant level of activity or with a major item of material. Cost categories in the cost structure must be well defined, and managers, engineers and others must have the same understanding of what is included in a given cost category and what is not included.
- Cost must be broken down to the level necessary to provide management with the visibility required in evaluating various facets of system design and development, production, operational use, and support. Management must be able to identify high-cost areas and cause-and-effect relationships.
- The cost structure and the categories defined should be coded in a manner to facilitate the analysis of specific areas of interest while virtually ignoring other areas.

Referring to Figure 2.1, the cost categories identified are obviously too broad to ensure any degree of accountability and control. The analyst can not readily determine what is, and what is not, included, nor can he or she validate the parameters that have been utilized in determining the specific cost factors that are input into the illustrated cost structure. The analyst requires much more information than is presented in Figure 2.1. In response, the cost structure illustrated in Figure 2.1 must be expanded to include a detail description of each cost category. Establishing the cost structure is one of the most significant steps in life-cycle costing. The cost structure constitutes the "framework" for defining life-cycle costs and ultimate cost control.

2. Time Costs

Time is valuable. And yet the value of time is often forgotten, particularly whenever someone compares dollar expenditures this year with those of next year and the year after, as if all of the dollars were equal. They are not. No military officer would suggest that a reserve infantry battalion arriving at the front line next week is equivalent to a battalion arriving today. Resources on hand today are usually worth more than identical resources deliverable tomorrow. Consequently, dollars with which we can buy resources today are worth more than dollars available tomorrow. Thus,

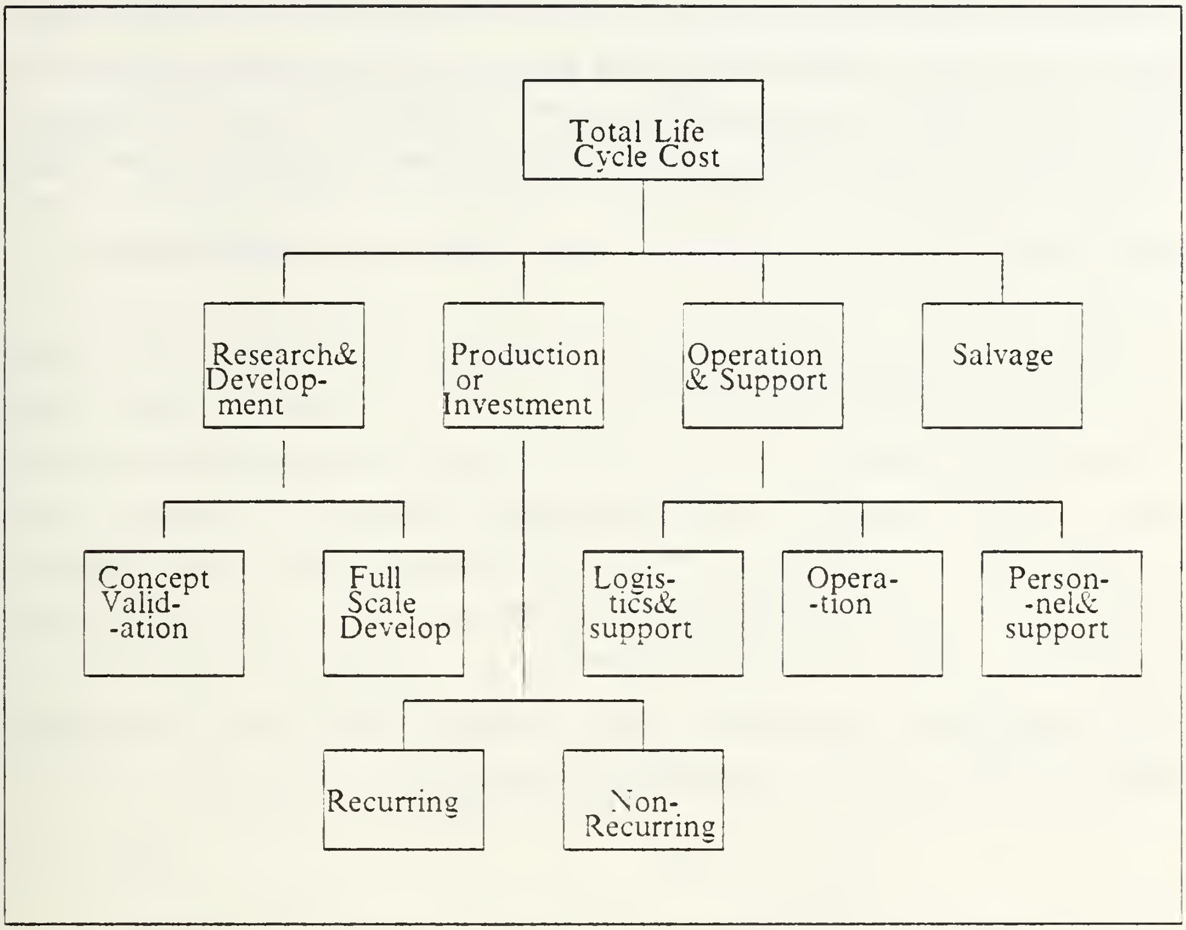

Figure 2.1 Cost Structure.

"discounting" should be considered when an analyst add together dollars spent or received in different periods, because they have different values than current dollars. Although there are numerous cost functions of time that might be significant in a cost-effectiveness analysis, there are two that are singled out here for discussion: (1)Discounted cost and (2)Obtainability cost.

There are two generally acknowledged reasons for discounting future costs. The first is to give recognition to the fact that in general there is a time preference for consumption such that a present monetary unit is worth more than a future monetary unit; and since it is worth more, it follows that procurement of that unit in the present represents a greater expenditure value than procurement of it in the future. For example, if a local savings bank will provide one dollar next year for every 90 cents deposited this year, or if the bank will provide 90 cents today in return for a promise to

pay 1 dollar next year, then is judged a dollar next year to be worth only 90 cents today. Future dollars might be discounted at rate of 10 percent per annum. This means: A dollar available next year will be judged as worth only 90 percent as much as a dollar available today. Similarly, a dollar available 2 years from today will be judged as worth only 90 percent as much as a dollar available next year(or 90% * 90% of a dollar on hand today) and so on. The above described situation can be expressed as:

$$M_{t+n} = M_t (1+r)^n$$

where

M_t = money value at present time

M_{t+n} = money value at a future time

r = discount rate per year

n = number of years

For a system funded annually over a period of years a serial process of discounting would be more appropriate, as described by the equation:

$$C_i = \sum_{i=0}^{n} C_t (1+r)^i$$

where

C_t = total system cost at present time

C_i = sum of costs during ith period

In the cost-effectiveness analysis this involves alternatives with different dates of obtainability. One method of rationalizing this concept consists of penalizing those alternatives that have later obtainability dates by raising their costs by the same compounding technique used previously to discount the cost. Therefore, M_{t+n} and C_i would be rewritten with negative exponents:

$$M_{t+n} = M_t (1+r)^{-n}$$

$$C_i = \sum C_t (1+r)^{-n}$$

The rationale for the case of obtainability in a system cost-effectiveness analysis is based on the dispropensity to wait(time preference) for the additional performance

and/or the lower cost obtainable from those systems with the later obtainability dates. By waiting, additional losses and/or costs might be incurred whose effects should be recognized. In effect, r is a measure of the rate of dispropensity to wait per period(for whatever lower cost and/or additional performance might be available in the future).

3. Cost Models

After the establishment of the cost structure, it is necessary to develop a model to facilitate the life-cycle cost evaluation process. The model may be a simple series of relationships or a complex set of computer subroutines, depending on the phase of the system life-cycle and the nature of the problem at hand. The cost model development is the derivation of the means for estimating the cost of each element. Several approaches may be used to derive the cost of the elements in a total system cost aggregation. Estimates of cost elements can be prepared by several techniques. One of the most common techniques is a cost estimating relationship(CER). A CER is an analytical device that relates the value(in dollars) of various cost categories to the cost generating or explanatory variables associated with the categories. There are several types of cost estimating techniques; parametric, industrial enginering, analogy, and expert opinion.

A parametric or statistical CER can be derived for new systems if there is historical data from prior systems that are functionally similar. Once a parametric relationship has been derived, it can be used to estimate the cost associated with the new system by direct substitution of the various design parameters and performance specifications into the cost equation. The cost is a function of cost factors as shown in below equation.

$$COST = f(X_1, X_2, X_3, \ldots)$$

$$\text{where } X_i = \text{the } i^{th} \text{ cost factor}$$

An example of a parametric CER which calculates the unit production cost of some equipment is the following equation.

$$Y = a + bX_1 + cX_2 + dX_3$$

where

Y = unit production cost of equipment of the ith unit

X_1, X_2, X_3 = cost factors

a,b,c,d = coefficient value

The unit production cost of the equipment can be computed by estimating the value of X_1,X_2 and X_3 The coefficients in the equations are prepared based on an analysis of historical data of appropriate equipment. The major advantage of this cost model construct is in the concept formulation stage of system design when only mission and performance envelopes are defined.

Industrial engineering CER's comprise the principle technique used to support cost estimates associated with electronic systems. It relies on detailed simulation of all the operations required to develop and produce a unique and specifically defined piece of equipment. In many cases, the estimating is done by a contractor. An analogy CER derive costs of new programs from data on past costs of similar programs. This technique frequently involves estimation of the incremental or marginal cost associated with program or equipment changes. The subjective or judgmental CER is derived from expert opinion. The advantage of this type of CER is that it is available when there is insufficient data for parametric CER's. It is, however, susceptible to bias., Increased program complexity can quickly degrade the estimates. and lack of verification and validation is always difficult.

C. EFFECTIVENESS

1. Concept of System Effectiveness

The system effectiveness is defined in general terms as "a measure of the extent to which a system can be expected to achieve a set of specific mission requirements". Mission requirements may be defined in terms of performance specifications for the individual items of equipment or in terms of overall operational accomplishments and goals for a service user. This measure of achievement is considered to be a function of important operational aspects. Operational aspects are similar to terms like availability, dependability, capability. These usually comprise what are called figures of merit(FOM) and serve as an index of the estimated quality of the system as it might operate under some assumed scenario. Sometimes a concept of "accountable factors" is used computationally to relate the FOM and measure of effectiveness(MOE) to important characteristics of the system. The type of system determines the specific system effectiveness elements, FOM, accountable factors and the mathematical

modeling used to evaluate alternative designs. For communication systems such FOMs are much more complex, primarily because of the multiple kinds of support provided to a great variety of users.

2. MOE Structure

There are several ways of expressing a measure of effectiveness. It may be expressed as a probability of achieving a certain level of performance. It may be a ratio of perfect, uninterrupted, unfailing, service to degraded service. However, before measuring the effectiveness of a system, the analyst must determine the elements which are appropriate for evaluating system effectiveness. The general elements which are appropriate for evaluating the expected effectiveness of a communication system (specially for TRI-TAC) are presented on Table 1.
The 16 elements are intended conceptually to be reasonably exhaustive and each element independent of others. Application of the 16 elements to some specific study may well disclose inherent mathematical interdependence and even the need to add new elements.

3. MOE Evaluation (Models)

The 16 general elements of system effectiveness presented in Table 1 will be used as the skeletal structure for developing a conceptual effectiveness model. A conceptual model is one which describes overall logic, principle elements, basic parameters, important assumptions, and "defining equations" which serve as a guidance for follow-on preparation of more detailed models for specific problems. The model helps to scope the degree of visability used for reporting of results of comparisons of trade-offs and design alternatives as well as the evaluation of test results.

The MOE model should be developed to assess the relative effectiveness of each of the alternatives. Having described the alternatives in detail, the relative differences between alternatives can be summarized. Based on this information the model can be tailored to highlight these differences by selecting only the MOEs that will yield different values for the alternatives. After the MOEs have been selected to highlight the alternative differences, the procedures in subsection techniques for measurement should be followed to complete the development of the effectiveness model to be used in the analysis.

TABLE 1

MOE ELEMENTS

a. Grade of service
b. Information quality
c. Speed of service
d. Call placement time
e. Index of availability
f. Lost message rate
g. Index of survivability(over attack)
h. Index of survivability(jamming)
i. Interrupt rate
j. Mobility
k. Transportability
l. Service features
m. Ease of reconfiguration
n. Spectrum utilization
o. Interoperability
q. Ease of transition

D. COST-EFFECTIVENESS ANALYSIS

Cost-effectiveness analysis is the combining of the effectiveness and cost results to select the preferred alternative. That is , the integration of the system cost and effectiveness models takes place. The purpose of the integration is to combine the expected values of system cost and effectiveness into a single common index for each alternative. This index then provides the basic framework for a rational cost-effectiveness decision making process.

The basic concepts inherent in cost-effectiveness analysis is applied to a broad range of problems. In analyzing the cost-effectiveness of systems the following prerequisites must be recognized.

- Common goals, purpose, or mission of the systems must be identifiable and at least theoretically attainable.
- Alternative means of meeting the goals must exist.
- Constraints for bounding the problem must be discernible.

Without common goals, the evaluation is meaningless. If there is only one feasible system for achieving the goal, there is no latitude for comparative evaluation. Further, without reasonable constraints for bounding the problem,by time, effectiveness, and/or cost, there is no framework within which the evaluation may be based. The system that costs more and/or can be developed later will be more effective. By recognizing and specifying constraints one bounds the evaluation and the preferred systems within these constraints can be identified.

A serious problem in cost effectiveness frequently arises when reference is made to the requirements associated with the goals or missions to be fulfilled by the systems. To give the goals tangible meaning, their requirements must be specified. These requirements will be referred to as a "mission requirement". Mission requirements are those attributes that must be met on evaluation of the systems to fulfill the goals. Evaluation criteria constitute measures by which the suitability of the candidate systems to fulfill the desired goals is judged or evaluated. The aim of the cost-effectiveness evaluation is to identify the system whose capabiiities meet the mission requirements in the most advantageous manner. The conduct of a cost-effectiveness evaluation is listed below:

- Define the desired goals, objectives, missions, or purposes that the systems are to meet or fulfill.
- Identify mission requirements essential for the attainment of the desired goals
- Develop alternative system concepts for accomplishing the missions.
- Establish system evaluation criteria(MOE) that relate system capabilities to the mission requirements
- Select fixed cost or fixed effectiveness approach
- Determine capabilities of the alternative systems in terms of evaluation criteria.
- Generate systems versus criteria array
- Analize merits of alternative systems.
- Perform sensitivity test.

- Document the rationale, assumptions, and analysis underlying the previous nine steps.
- Choose the most attractive alternative based on the concept of minimum cost per unit effectiveness among different alternatives.

E. MEASUREMENT TECHNIQUES

1. Methodology

After the proper MOEs are selected to measure the system, each MOE should be calculated and combined. There are various methods for assessing the MOEs. The methods presented fall into the following categories; a) full dimensionality b) single dimensionality c) intermediate dimensionality and the d) hybrid method.

Full dimensionality consists of starting with n-attributes(dimensions) and reducing the dimensionality to some lower value. Two methods that utilize all of the attributes are the dominance and satisficing method. In the dominance method, the decision maker relies on intuition to select an alternative from the dominating one by comparing the subjective value of the alternative. The satisficing method requires the decision maker to establish the minimum attribute values that an alternative's attributes must have. These two methods are effective in reducing the number of alternatives, but usually do not result in the selection of a preferred alternative.

Single dimensionality method reduces n-dimensions to one-dimension by removing all but one dimension. The method can be divided into a) maximin b) maximax c) additive waiting d) effectiveness index e) lexicography f) utility theory. The maximin method reduces n-dimensions into a single dimension by examining attribute values across alternatives and noting the lowest value for each alternative. Then by selecting the alternative with the most acceptable value across the lowest attributes, a preferred alternative is selected. Maximax methodology characterizes alternatives by their best attribute and then compares them by selecting the highest attribute value across alternatives. Additive weighting consists of assigning weights to all attributes that reflect the relative importance of each as a percentage of the total. For comparability, summation of the weight are normalized to one. Highest weighted average is selected. The effectiveness index method uses weights in a functional form, fitted for the system and, unlike additive weighting, need not be a summation operation. That is, the

function is defined in terms of the attributes associated with the system under consideration and this function might be an exponential, logarithmic, or any other mathematical operation. The lexicography method is a single dimensional technique because one dimension at a time is considered. In a dictionary like manner, the attributes are ranked with respect to relative importance as viewed by the decision maker. Utility theory considers the effect of multiple events rather than multiple attributes to select the best alternative. This method is usually employed when there is great amount of uncertainty about the outcomes of the various attributes.

Intermediate dimensionality categories lie in more than one but less than the full dimensionality. There are two methods here. First, trade-off method is easy to explain by answer the question like this. If an attribute value is lowered for a certain attribute, then how much of an increase in value will another attribute be raised? By the way, this method is most useful in designing alternatives rather than selecting them. Second, nonmetric scaling method consists of taking k-attributes that have been chosen from the original n-attributes and comparing or measuring them to an ideal alternative that lies in the k-dimensional space.

Hybrid method, which is TRI-TAC FOM, was developed to combine multi-MOE assessments for subsystem planning evaluations. The method is a combination of additive weighting, effectiveness index and utility theory. The method consists of the following steps; a) establish MOE weight b) assign utilities to MOE assessments c) calculate the FOM [Ref 10:p.33].

2. Techniques for Measurement

Cost-effectiveness analysis and its two major elements, life-cycle cost and system effectiveness are oriented toward mathematical optimization techniques. Mathematical optimization techniques lead to the same goals as cost-effectiveness, that is, for guiding the problem solver to that choice of variables that maximizes the "goodness" measure or that minimizes some "badness" measure. The analysts objective is to find and identify the one design vector, X, out of all feasible alternatives, which maximizes some objective function f(X), that is:

$$f(X) = \max f(x)$$

subject to some suitable constraints. The analytical objective is to identify the design, among proposed alternative designs, that maximizes system effectiveness; subject to a cost constraint plus other constraints, for example , quantity of equipment, time schedule, and risk. The MOEs are useful in defining the above objective function. Thus, system effectiveness is a function of such MOEs as grade of service, information quality, etc. They may used singly or in some combination along with appropriate weights so as to constitute a meaningful figure or figure of merit.

Here is one example of a technique for measuring a MOE. Grade of service(GOS) is the MOE. It estimates the probability that a request for communication service will be blocked. Blockage is defined to

- Include calls preempted by higher priority users
- Exclude calls incompleted to busy subscribers

GOS is computed for blockage occuring during the estimated peak period of traffic called the "busy hour". Methods for calculating GOS average the grade of service for all pairs of subscribers as weighted by the magnitude of the traffic needs. If the probability of blocking is considered to be the ratio of blocked calls to the total offered traffic, the following equation can be written:

$$GOS_j = \frac{\sum (e_i \, GOS_i)}{\sum e_i}$$

where

GOS_j = the network grade of service

GOS_i = the grade of service of the i^{th} needline

e_i = the traffic offered to the i^{th} needline

After calculation of each MOE, in the case of a hybrid Figure of Merit approach, whether qualitative or quantitative, each MOE can be normalized into a 0 to 10 numerical rating. The utility information is obtained from the decision makers. To obtain a FOM combine the weighting and utility information using the following equation for each alternative:

$$FOM_i = \frac{\sum W_j \, U_{ji}}{\sum W_j}$$

where

FOM_i = the figure of merit for the i^{th} alternative

W_j = the weight of the i^{th} MOE

U_{ji} = the utility assigned to the i^{th} alternative with respect to the j^{th} MOE

With this FOM, the relative ranking of alternatives with respect to effectiveness is determined. But it should be noted that this approach magnifies the differences between alternatives. An alternative method would be to consider the weights and utility values of all MOEs. This technique would result in the same ranking but the differences would be less significant.

III. COST MODEL

A. OVERALL COST MODELING FRAMEWORK

To develop the cost model for a fiber optic cable(FO) or a communication satellite(SAT) system, the following steps will be taken:

(1) Set up the life-cycle cost structure for FO/SAT,

(2) Identification of cost elements,

(3) Development of model.

Overall assumptions about fiber optic cable and satellite cost structure and performance should be made to avoid unnecessary complexity of modeling, and to make a comparison possible between alternatives. General assumptions pertinent to the development of the model are specified below:

- R&D and Salvage cost will be assumed zero. Those costs which are incurred during the development phase are considered sunk costs for this study and are not included in the analysis. Salvage cost which is incurred at the end of life-cycle for equipment simply is assumed zero.
- The time horizon will be considered from the present to 2010.
- This thesis will concentrate on investment cost; O&S cost will not be developed as a detailed model but estimates an annual lump sum.
- Since the R&D and Salvage cost are assumed zero, total system cost will be calculated as shown in Table 2.

B. SATELLITE COST MODEL

1. Cost Structure

To develop the cost model using the concept of LCC, the satellite cost break down structure is illustrated on Figure 3.1. Since R&D and salvage costs are zero, no break down of costs is included. O&S and investment costs are broken down to the sublevel where the cost data is available.

TABLE 2

TOTAL SYSTEM COST FOR SAT/FO

R = Research and Development

I = Investment

	SAT	FO
I_1 =	earth station	basic terminal
I_2 =	space segment	repeater
I_3 =	.	cable
	.	

A = Annual operating cost

S = Salvage

$$* \; TSC = R + I + \sum A_t - S(R,S = 0)$$
$$= I + \sum A_t$$

A_t = Annual system life-cycle operation cost

TSC = Total system cost

$I = I_1 + I_2 + I_3 \ldots$

2. Cost Elements

The total system life-cycle cost structure is subdivided into lower level cost elements and presented in Table 3. The TRI-TAC report is the main source for cost elements [Ref. 4: p. 13].

(1)Investment Cost

Historically investment cost has been the decisive factor in making system decisions. Investment cost for major systems represents approximately 45 to 47 percent of the LCC after 10years of operations [Ref. 5: p. 101]. Referring to Figure 3.1,

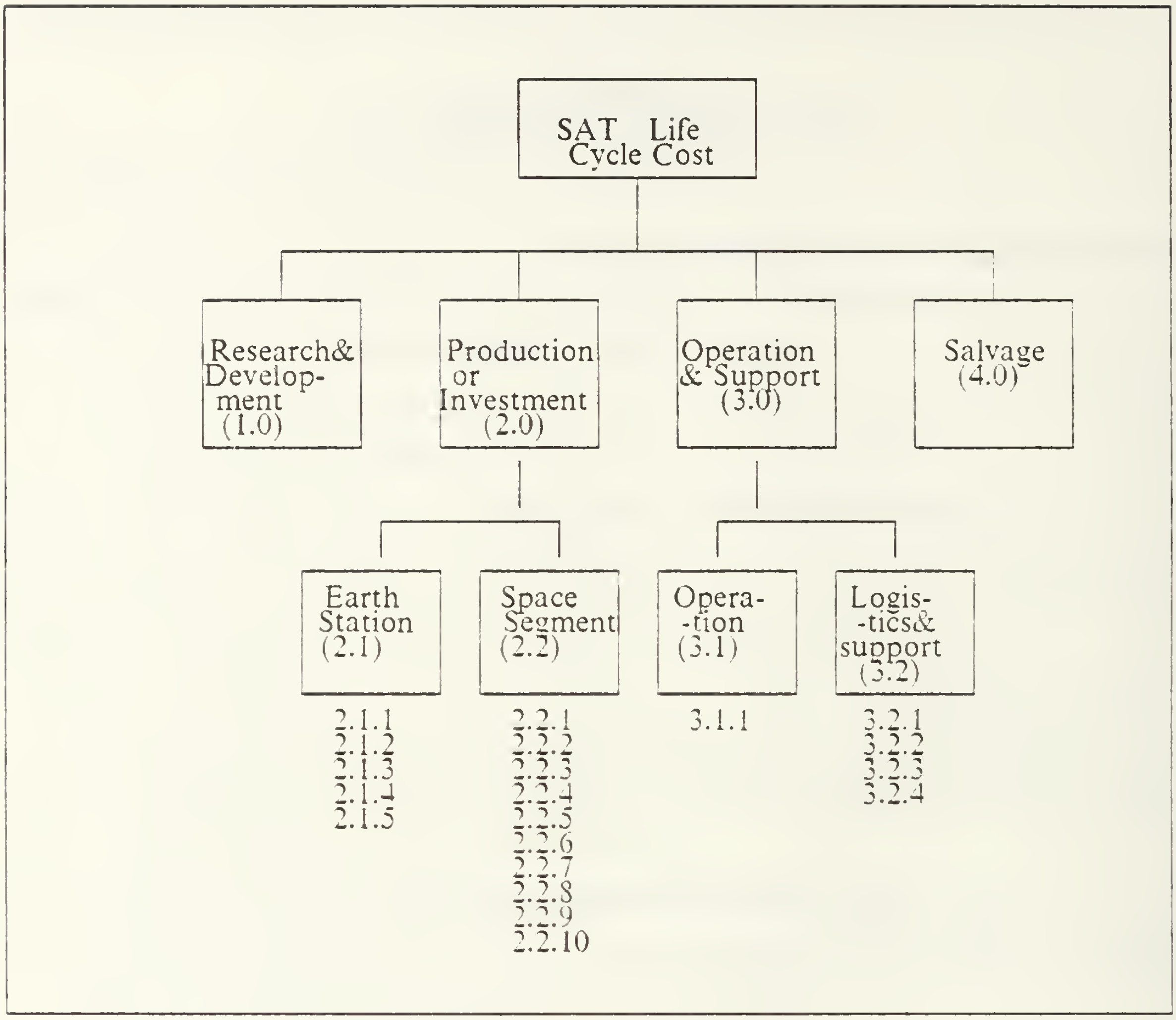

Figure 3.1 SAT Cost Structure.

satellite investment cost consists of two parts, earth station and space segment. The earth station cost elements are as follows:

- Antenna(I_a); The cost depends on the antenna diameter. Diameter usually varies between 4m - 12m. The large antenna includes cost of tracking and frequency reuse.
- LNA(low noise amplifier, I_l); C-band LNA costs are divided into nonredundant and redundant units. The redundant unit includes cost of automatic switching between two LNAs.
- HPA(high power amplifier, I_h); The costs of C-band traveling wave tube(TWT) power amplifier varies the output power between 5W -3KW.
- Converter(I_c); It consists of up and down converters.

TABLE 3

SAT COST ELEMENTS

1.0 Research and Development

2.0 Investment

2.1 Earth station equipment
- 2.1.1 Antenna
- 2.1.2 LNA
- 2.1.3 HPA
- 2.1.4 Converter
- 2.1.5 Installation

2.2 Space segment
- 2.2.1 Structure
- 2.2.2 Thermal control
- 2.2.3 Propulsion
- 2.2.4 Electrical power supply
- 2.2.5 Launch vehicle & orbit operations support
- 2.2.6 Ground equipment
- 2.2.7 Communications(mission)
- 2.2.8 Attitude control
- 2.2.9 Program mgmt
- 2.2.10 TT&C

3.0 Operation and Support

3.1 Operation
- 3.1.1 Operational personneis

3.2 Logistics and support
- 3.2.1 Maintenance facilities and personnel
- 3.2.2 Supply support
- 3.2.3 Test and support equipment
- 3.2.4 Spare parts

4.0 Salvage

- Installation(I_c); Installation costs are usually considered as 40% of total earth station equipment costs.

A typical C-band large earth station consists of an 11 meter antenna, 50° LNA and 3Kw HPA. The 0.995 availability can be satisfied with a single thread earth station. The 0.999 availability requires all components to be redundant. For existing C-band satellites, it is cost effective to provide 32 Mbps, by using the full transponder 60 Mbps TDMA approach [Ref. 6: p. 93].

In costing end-to-end service, one earth station will be considered as a cost factor and the other major component is the cost of the space segment. The typical C-band satellite consists of 24 and 36Mhz wide transponders(see appendix E). It uses horizontal and vertical polarization. For a typical satellite system it is assumed that two satellites will be launched and one will be a ground spare. The initial investment for the space segment consists of various elements:

- Structure(I_{st}); It provides the support and mounting surfaces for all equipment, and bears the majority of spacecraft dynamic stress loads. Typical equipment includes struts, antenna supports experimental booms, and mechanical equipment.
- Thermal control(included in I_{st}); It maintains the temperature of the spacecraft platform and mission equipment within allowable limits in certain orbital conditions. The thermal control includes paint, insulation, temperature sensors and heat pipes.
- Propulsion(I_{pr}); It provides reaction force for a final maneuver into orbit and orbit changes. Typical equipment includes solid rocket motors, firing squibs, liquid engines, tanks, nozzles and tubes. The apogee motor is normally used to insert the spacecraft into synchronous or low-earth orbit.
- The electrical power supply(I_{ep}); EPS subsystem generates, converts, regulates, stores, and distributes all electrical energy to and between spacecraft components. Typical equipment includes solar cells, regulators, converters, power distribution units, batteries and wire hardness.
- Launch vehicle and orbital operations support(I_{lv}); It includes any effort associated with planning for and execution of the launch and orbital operations effort.
- Ground equipment(I_{ge}); It includes ground support equipment, in-plant equipment, special tools and test equipment, and any nonhardware efforts associated with ground equipment.
- Communications(I_{cm}); This subsystem performs a transmission repeater and signal conditioning function. Communications costs include the hardware and non-hardware communications equipment such as, receiving antennas, receivers, traveling wave tube amplifiers, transmitters, transmitting antennas, RF switches, switch control units and phased array control units.

- Attitude control(I_{ac}); The system maintains the spacecraft in the required orbit. It also maintains the correct attitude and direction of determined axes within that orbit by sensing the spacecraft attitude at all times and making necessary adjustments.
- Program level(I_{pl}): It includes program management, reliability, planning, quality assurance, system analysis, project control and other costs.
- Telemetry, Tracking and Command(I_{tc}); This performs one or more of the following functions; measures important spacecraft platform conditions, processes this information and also mission data, stores such data, transmits data to ground, receives and processes commands from ground and initiates their execution, and provides a tracking capability. Typical equipment includes analog/digital converters, coders, digital electronics or computers, signal conditioners, format control units, transmitters antennas, receivers, decoders, switching relays, tape recoders, amplifiers and clocks.

(2)Operation and Support Cost

Operating costs are the recurring program element costs required to operate and maintain the capability as well as the costs associated with introducing improvement to extend the equipment service life. Operating costs include those costs for personnel pay and allowances, equipment maintenance, training, logistics support and consumables.

- Operations: This category includes cost associated with the use of the equipment. The cost incurred as a result of direct operation of the equipment and items actually consumed in operation of the equipment are included in this category.
- Operating personnel: It covers the total costs of operating the system for the various applications. Since the operator is charged with a number of different duties, only that allocated portion of time associated with the direct operation of the system is counted.
- Maintenance facilities and personnel: The cost is based on the occupancy, utilities, and facility maintenance costs as prorated to the system. Facilities cost in this case is primarily related to the earth station maintenance. Personnel cost means that the cost of training related to maintenance personnel.

- Supply support: This element includes the cost of personnel, material, facilities and other direct and indirect costs required to maintain and support the equipment and for system during the operational phase of its life-cycle.

3. Cost models

The satellite cost model will be developed based on the previously discussed cost structure and elements. Each cost element has its own cost equation. This thesis develops the cost model with the concept of parametric cost estimation relationship's equations(case one). However, some of subsystem level cost equation parameters are hard to determine because of limited data and lack of previous studies. Case two will be a simple mathematic summation. Both cases will contribute to the calculation of the satellite cost later on chapter Five.

(1) Earth station

Since the earth station investment cost depends on the size, the cost equation will be derived from size. Table 4 and 5 shows the process of model development of the earth station cost. Referring to case one, the earth station size is determined by maximum capacity for processing information. Depending on the capacity of the earth station, cost is determined. The graph is shown in Figure 3.2:

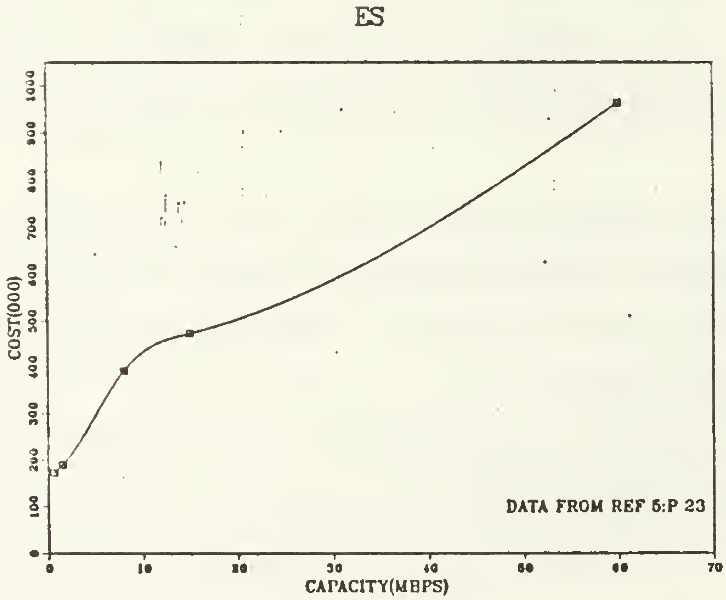

Figure 3.2 Earth station cost.

TABLE 4

EARTH STATION INVESTMENT COST CASE 1

$I_e = f(\text{ size })$

$:I_e$ = Investment cost of earth station

*Size: large (capacity 32 Mbps)

medium(capacity 6.3Mbps)

small (capacity 1.5Mbps)

$I_e = a\, X_s{}^b$

$:X_s$ = earth station size

:a, b = coefficients

Referring to case two, installation cost is included in the integration cost. The earth station subsystem cost can be broken down for more detailed cost level analysis.

TABLE 5

EARTH STATION INVESTMENT COST CASE 2

$I_e = I_1 + I_2$

$:I_1$ = earth station subsystem cost

(including ANT, LNA, HPA, converters)

$:I_2$ = installation cost

(40% of earth station subsystem cost)

$I_e = I_1 + 0.4I_1$

$= 1.4I_1$

For example, I_1 consists of ANT, LNA, HPA and converters. Antenna cost varies from a diameter of four to 13m. A simple but flexible function to represent this cost element is given by:

$$I_a = f(\text{ diameter })$$

$$I_a = a X_d^{\,b}$$

: X_d = ANT cost with different diameter

: a, b = coefficients

If the LNA and HPA are involved, the low degree LNA cost will be higher with higher degrees. The degree ranges are from 40° to 120°. HPA cost depends on the output level of the amplifier which ranges from 5w to 3Kw. Each graph will be developed as shown Figure 3.3:

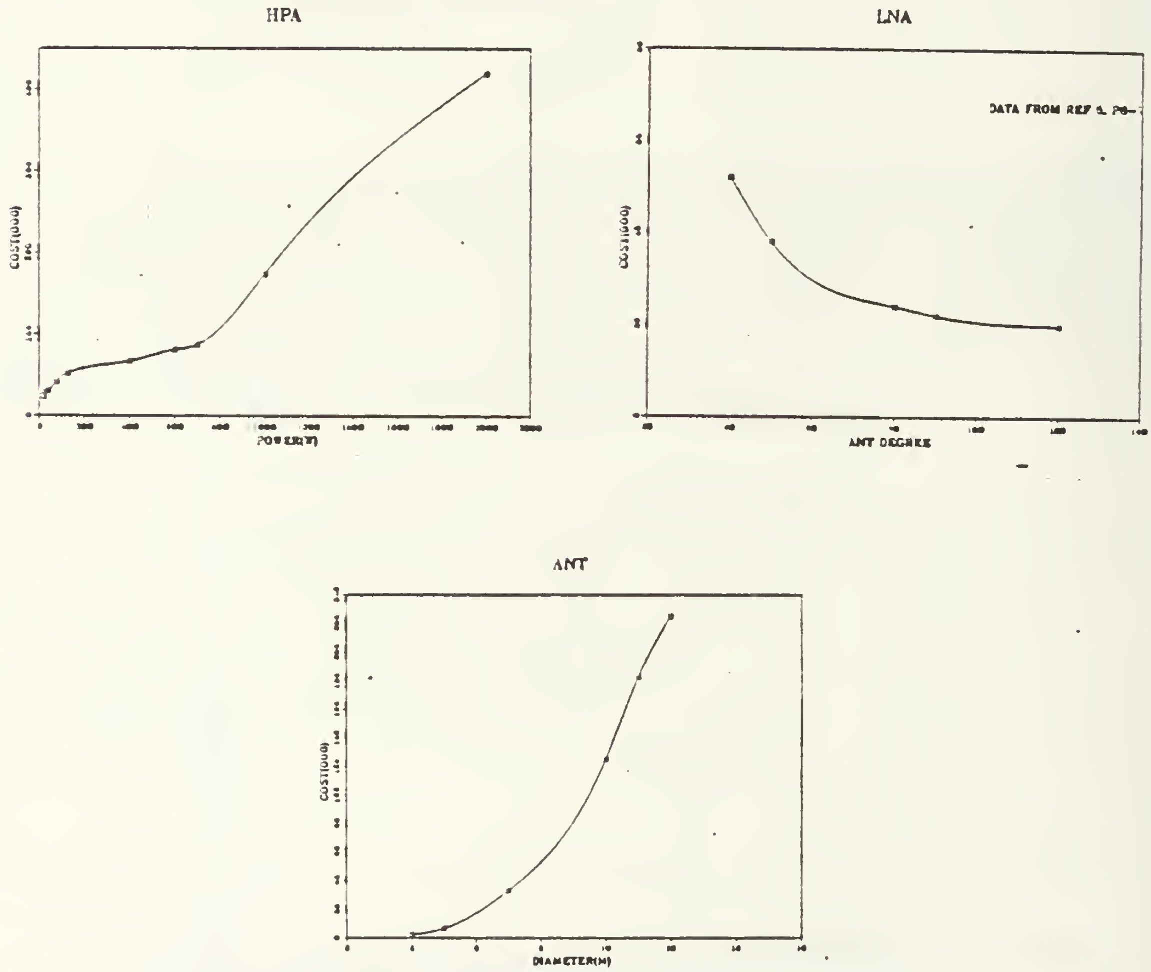

Figure 3.3 Subsystem cost.

Generally speaking, there are several types of different curve shapes depending on the coefficient values(Figure 3.4).

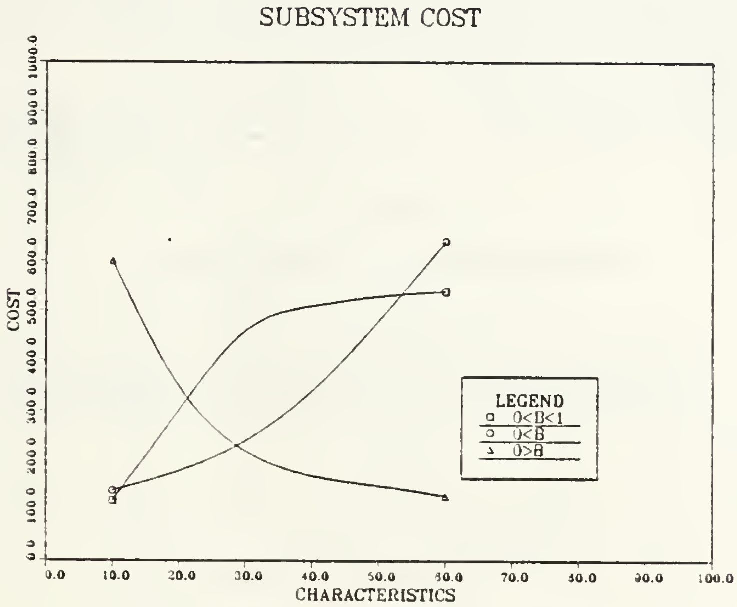

Figure 3.4 General curve.

In other words, the detailed subsystem level cost equations will be determined from different forms of the CER parametric equations depending on the different situation and data. Examples of possible standard equation forms are:

$$Y = a + bX$$

$$Y = a + bX + cX^2$$

$$Y = a + bx_1 + cX_2 + dX_3$$

$$Y = a + bX_1 + cX_2{}^2$$

$$\text{Log } Y = \text{Log } a + b\text{Log } X \text{ (or } Y = aX^b \text{)}$$

where

Y = Dependent variable (cost)

X = Independent variable(physical or performance characteristic)

This variety of mathematical functions can be fitted by using least-squares procedures, however, this thesis will not be concerned with building CER's through regression analysis, because of data limitation.

(2) Space Segment

The space segment consists of the cost elements given in Table 6 and 7. Every subsystem level has its own equation. Since the CER equations are available in the other references, the equations are quoted for only space segment [Ref. 7: p. 4-6]. In case one, the space segment cost will depend on the number of satellites, type of launch vehicles, insurance, and recurring and non-recurring cost.

TABLE 6

SPACE SEGMENT COST CASE 1

I_s = f (number of satellites, launch vehicle cost per satellite, insurance cost per satellite, cost of spare satellite)

$I_s = N * [R + L + IN + OH] + S$

N = number of satellite

R = recurring satellite cost

L = launch vehicle cost

IN = insurance cost

OH = other overhead

S = cost of back up satellite

In case two, the parametric equations given in other studies are added to calculate total space segment cost. Total satellite investment cost can be computed by:

$$I_t = I_e + I_s$$

$$= 1.4 I_1 + N * [R + L + IN + OH] + S$$

or

$$= a X_s^b + N * [R + L + IN + OH] + S$$

I_t = SAT investment cost

I_e = Earth station cost

I_s = Space segment cost

TABLE 7

SPACE SEGMENT COST CASE 2*

(Non-recurring investment cost)

$$I_s = I_{st} + I_{pr} + I_{ep} + I_{lr} + I_{ac} + I_{cm} + I_{pl} + I_{tc}$$

$$I_{st} = 1203.97 + 112.93\,X^{0.66}$$
$$I_{pr} = 223.37 + 0.01075\,X$$
$$I_{ep} = 360.97 + 0.0165\,Y$$
$$I_{lv} = 27.44 + 0.2992\,X$$
$$I_{ac} = 960.72 + 72.54\,X$$
$$I_{cm} = 564.68X^{0.56}$$
$$I_{pl} = 7414.16 + 22.60X$$
$$I_{tc} = 892.08 + 41.18X$$

where

I_{st} = structure and thermal control
I_{ep} = the electrical power supply
I_{lv} = launch vehicle and orbital operations support
I_{ac} = attitude control
I_{cm} = communications
I_{pl} = platform
I_{tc} = TT&C
X = weight(Lbs)
Y = output power(Kw)

*Data from Ref 6: p.iv-6.7

C. FIBER OPTIC COST MODEL

1. Cost Structure

The fiber optic life cycle cost structure is shown by Figure 3.5. The concept of a cost structure will be the same as the SAT one. However, the cost elements of fiber optic cable are different from SAT.

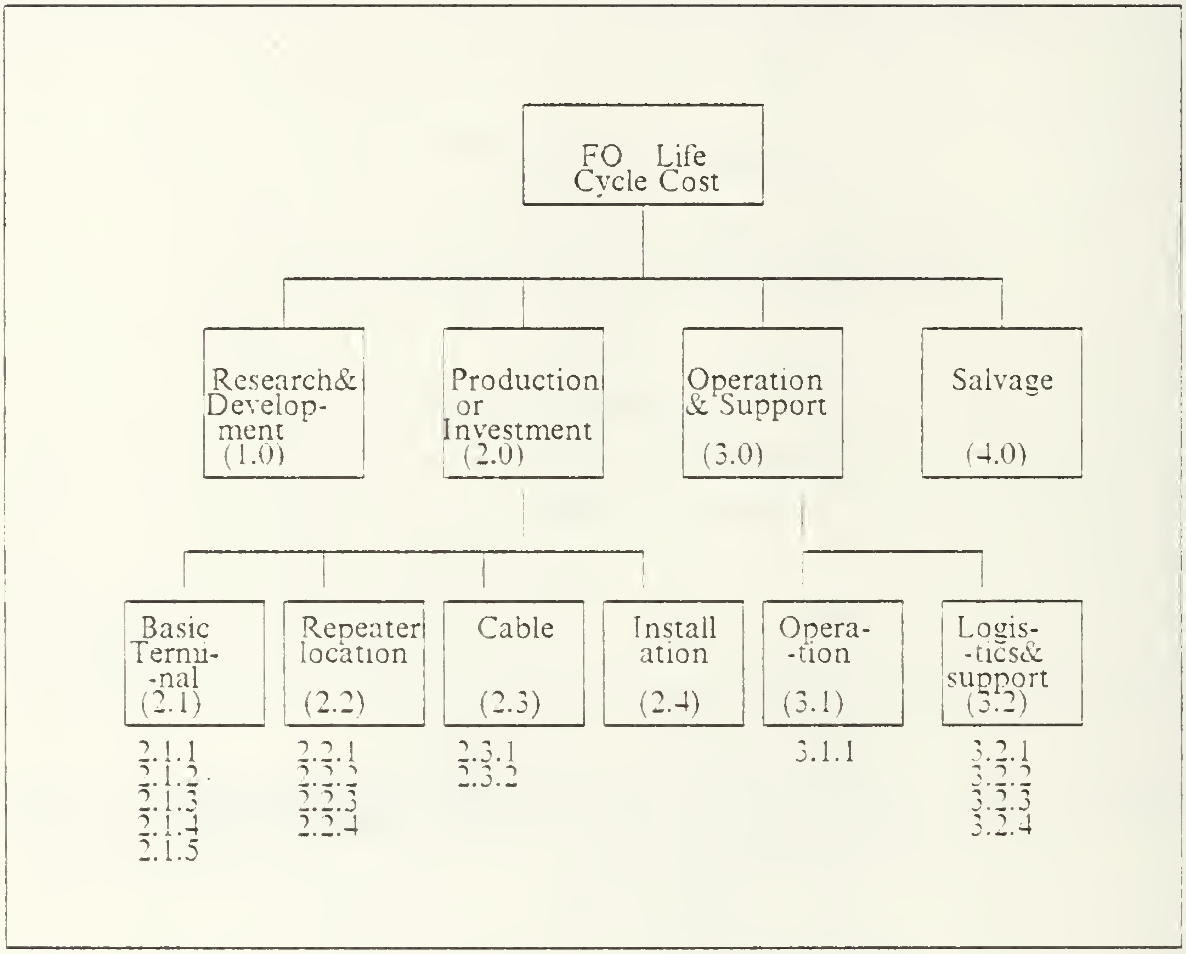

Figure 3.5 FO Cost Structure.

2. Cost Elements

Fiber optic cable systems consist of the following main parts as shown in Table 8: Terminal system. Repeater system, Cable and Installation.

(1)Investment Cost

TABLE 8

FO COST ELEMENT

1.0 Research and Development

2.0 Investment

2.1 Basic terminal
- 2.1.1 Optical terminal
- 2.1.2 Fault & alarm system
- 2.1.3 Power system
- 2.1.4 Test equipment
- 2.1.5 Spares

2.2 Repeater location
- 2.2.1 Optical repeater
- 2.2.2 Charger and battery
- 2.2.3 Enclosure

2.3 Cable
- 2.3.1 Material

2.4 Installation

3.0 Operation and Support

3.1 Operation
- 3.1.1 Operational personnel

3.2 Logistics and support
- 3.2.1 Maintenance
- 3.2.2 Training
- 3.2.3 Support equipment
- 3.2.4 Spare parts

4.0 Salvage

- Cables(C_c): Optical cables for submarine application are designed to protect the fibers against pressure at 5500m depth, and water penetration affecting transmission properties. The design of the cable shall inhibit the ingress of water into the cable structure under normal operating condition. This is an essential requirement for long term stability of the transmission characteristics. Generally, it is required that in the event of cable damage, the maximum cable length to be replaced due to water ingress from the point of the damage must

not exceed 2000m for the deep water cable and 500m for shallow water cable. The present generation of submarine FO cables accommodate up to 6-8 optical fibers per cable.

- Repeaters(C_r): The intermediate repeaters for submarine systems are still in the process of development and the values indicated for the various parameters should be considered with careful inspection of parameters. The repeater spacing will be assumed as 40-45km adopting present technology. Each repeater location has enclosure facilities with emergence battery and charger.
- Terminal(C_t): The terminal consists of several equipment types such as the power system and the repeater supervisory system as well as basic optical terminal. The power for long submarine links needs about 6kv for each terminal with an overall voltage on the link of about 12kv. The power requirements for the repeaters depend on the power of each regenerator and the number of regenerators. The supervisory circuit is an important part because location of fault points and the degraded repeaters from the end stations is necessary for maintaining a cable system.
- Installation(C_i): Installation cost will include installation of the subsystems.

(2) Operation and Support cost

This cost element concept is the same as SAT shown before.

3. Cost Models

FO cable investment cost consists of three main subsystems. Each subsystem has its own detailed elements. The equations shown in Tables 9 and 10 describe the simple additive method and the parametric method [Ref. 8: p .319]. The case one model is a simple additive model. Each three subsystems include installation cost. Cable material installation costs are specified by cost per distance for different areas of installation (e.g.,large city, suburbs and rural areas). This case one model uses a 90Mbps capacity fiber optic cable system.

For the case two model, the coefficient values are compared and calculated in terms of existing copper cable system. Referring to C_f in Table 10, the cable cost coefficient value of "a" must account for the cost of those fibers with due consideration

TABLE 9
FO INVESTMENT COST CASE 1

C_f = f(terminal system, repeater system, cable)

$C_f = C_t + C_r + C_c$

$C_t = C_{tm} + C_{fa} + C_{ps} + C_{ts} + C_{im}$
$C_r = C_{rl} + C_{cb} + C_{en} + C_{in}$
C_c :

Material	3.8 Per Km (KS)
Installation	
Large city	10.0 Per Km
Suburbs	7.0 Per Km
Rural	3.0 Per Km

C_f = FO system cost
C_t = Terminal system cost
C_r = Repeater system cost
C_c = Cable cost
C_{tm} = Terminal cost
C_{fa} = Fault and alarm system cost
C_{ps} = Power system cost
C_{ts} = Test equipment and spare cost
C_{im} = Installation and miscellaneous cost
C_{rl} = Repeater and location cost
C_{cb} = Charger and battery cost
C_{en} = Enclosure cost
C_{in} = Installation cost

* 90Mbps general purpose cable

of amount of fiber used. The number of fibers and the cost of each tends to drive "a" to large values. The other coefficients are also derived by this concept which is the comparison with copper cable versus fiber optic cable characteristics. The coefficient values shown in the Table 10 are derived based upon other information [Ref. 8: p. 299]. Since this data refers to TAT-6, new coefficient values should be estimated when TAT-7 or TAT-8 is used.

TABLE 10

FO INVESTMENT COST CASE 2

C_f = f (terminal system, repeater system, cable, installation)

$$C_f = aC_t + bC_r + cC_c + dC_i$$

$1.5 < a,b < 2.0$

$c = 1.0$

$0.4 < d < 0.7$

C_t = terminal cost

C_r = repeater location cost

C_c = cable cost

C_i = installation cost

C_f = FO investment cost

*Submarine cable

This model only can calculate the investment cost by knowing four related subsystem cost in advance.

IV. EFFECTIVENESS MODEL

A. OVERALL MODELING FRAMEWORK

System effectiveness for SAT/FO depends on system performance and system characteristics. The important system characteristics can be considered with the help of the schematic diagram shown in Figure 4.1 [Ref. 9: p. 13]. From these system characteristics, we can select related MOE elements in Table 11. These elements are divided into four conceptual MOE structures: communication measures, stability measures, reorganization measures, and security. Five elements will be discussed for the SAT/FO effectiveness model. Security will not be discussed in this thesis.

TABLE 11
MOE STRUCTURE

*Communication measures :	1. GOS (grade of service) 2. IQ (information quality) 3. SOS (speed of service) 4. CPT (call placement time) 5. SU (spectrum utilization)
*Stability measures :	1. IOA (index of availability) 2. IR (interrupt rate)
*Reorganization measures :	1. EOR (ease of reconfiguration) 2. EOT (ease of transition)
*Security	

The reasons for representing effectiveness in four categories is twofold. First, this representation aids the decision maker in the individual assessments of the MOEs. Second, the four areas depicted naturally represent different functional design areas that must be considered. However, the reason why only five elements will be discussed is that the exact effectiveness measure with detailed performance characteristics is needed much more detailed efforts with detailed data. Thus, more detailed effectiveness measures should be extended for future Korean communications.

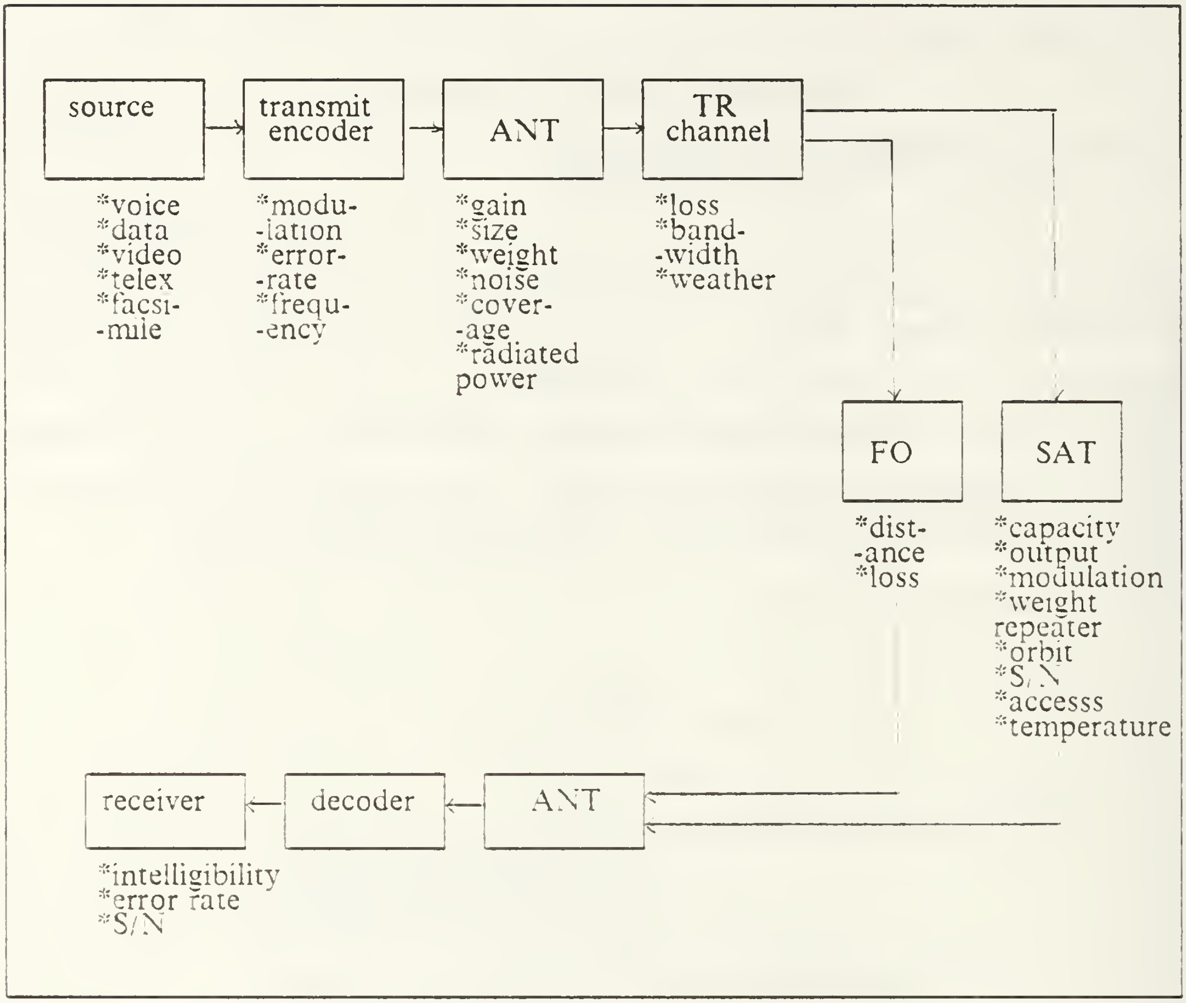

Figure 4.1 Related Factors of MOEs Selection.

After selection of these MOEs, each should be combined. The method is a combination of additive weighting, effectiveness index and utility theory, and can be used to produce a single numerical effectiveness result from quantitative assessments, qualitative assessments, or a combination of both types of assessments. The method consists of the following basic steps:

- Establish MOE weight
- Assign utilities to MOE assessments
- Calculate the FOM

B. MOE ELEMENTS FOR SAT/FO

1. Grade of Service(GOS)

Grade of service is an estimate of the probability that a request for communication service will be blocked. For a network, it may be computed as a weighted average of blocking probabilities over all user pairs. The weights are computed based on selected characteristics of traffic needs for each user pair [Ref. 10: p. 39]. Some of the general conditions limiting the application to systems are below:

(1) The type of elements of service requested are:

a. Voice, data, video, telex or facsimile

b. Direct, indirect, broadcast, or conference

c. Direct dialed, preprogrammed conference, or dedicated circuits

d. Precedence level

e. Secure, approved, or non-secure

(2) GOS is computed for blockage occurring during the estimated peak period of traffic, called the "busy-hour".

GOS is often used as a circuit and/or network sizing parameter. It permits the evaluation of how much capacity is required to handle estimated traffic loads. GOS can be used as an indication of the effectiveness of a system network design which is constrained to a certain cost level. System parameters vary with total cost and the grade of service is calculated for each design. The network design with the best grade of service is the optimum for a fixed level of cost. GOS is defined as follows:

$$G = f(T, C, R, A, D)$$

where

G = GOS for the total network,

T = Traffic volume by type of service,

C = Channel capacity,

R = Alternate routing capability,

A = Call or message arrival probability distribution,

D = Call or message duration.

2. Information Quality(IQ)

In general IQ is the fidelity or exactness with which the received signal represents the transmitted signal [Ref. 10: p. 42]. Some of the conditions and qualifications are:

(1) The information is transmitted during busy-hour traffic.

(2) All equipment is in perfect working order.

(3) Important aspects of IQ include Bit Error Rate(BER).

BER is the estimated fraction of bits sent that are incorrectly received. Other aspects are intelligibility and speaker recognition. IQ is defined in the following way:

$$I = f(\, S, W, K, D, P, M \,)$$

where

I = Estimate of IQ for each relevant item of equipment in a network, I_n .or an equipment string, I_g,

S = Signal to noise ratio,

P = Power level,

W = Band width,

K = Crosstalk,

D = Percent distortion,

M = Modulation scheme and coding.

IQ estimates are made separately for each mode of information transfer. The most general measure of IQ is the bit error rate of the information delivered to the digital terminal by the transmission system. The BER delivered includes any error rate reduction by error control devices. For a particular terminal and data format, it might be appropriate to express the error rate in terms of character, block, or message error rate.

3. Speed of Service(SOS)

SOS is the expected time for a message requires to move through the network from the last bit out of the sending terminal to the last bit into the receiving terminal.

This is an average over all user pairs weighted in accordance with traffic demand [Ref. 10: p. 49]. Some of the conditions that may be important for evaluation are:

(1) The connection is attempted during busy-hour traffic.

(2) All equipment is in perfect working order.

(3) The precedence of the call is specified.

The SOS is the time required to move a message through a network. The time for a message to pass through a network is a function of following parameters:

a. Switching rate,

b. Routing plan,

c. Human message handling speed,

d. Dialing method,

e. Precedence level,

f. Processor speed and capacity,

g. Queueing.

This measure must be distinguished from "call placement time" which treats the time required to connect one subscriber to another. In the case of a message, the time required to dial the message switch can be considered analogous to the time required to place a voice call which is call placement time. The call placement time is so much smaller than the speed of service, that CPT can normally be considered to be negligible for message traffic.

4. Index of Availability(IOA)

The weighted average over all subscriber pairs of the ratio of accepted traffic of a specific type over an imperfect system to accepted traffic over a perfect system, when an imperfect system has equipment failures but a perfect system has none. The average is weighted in accordance with the traffic demand matrix [Ref. 10: p. 54]. The general evaluation conditions are below:

a. The measurement is made during busy hour traffic.

b. All system executions are normal except those caused by faulty equipment.

c. Traffic blockages do not contribute to unavailability

d. The type of call is specified.

The above definition, coupled with the qualifying conditions, forms the point of departure for the analysis of the index of availability MOE. The conditions and delineations are to restrict the study of this MOE to the normal operating stress on the system that results from equipment failure and to eliminate from consideration any other stress situations. Availability treats the basic problem of what fraction of the time a system or equipment is in an operational state as opposed to the time that it is in a down state as a result of equipment failure. The mathematical equation that expresses the above concept is [Ref. 11: p. 337]:

$$\text{Availability(A)} = \frac{\text{Uptime}}{\text{Total time}}$$

It can also be written as:

$$A = \frac{MTBF}{MTBF + MDT}$$

where

MTBF = Mean Time Between Failure
(a function of reliability)

MDT = Mean Down Time
(a function of maintainability)

There are three forms of availability- inherent(A_i), achieved(A_a), and operational(A_o). These three categories are a function of how the MDT is defined.

$$A_i = \frac{MTBF}{MTBF + MTTR}$$

where

MTTR = Mean Time to Repair

$$A_a = \frac{MTBF}{MTBF + (MTTR + MTTP)}$$

where

MTTP = Mean Time to Perform scheduled Maintenance

$$A_0 = \frac{MTBF}{MTBF + MDT}$$

where

MDT = Mean Down Time

5. **Ease of Transition(EOT)**

The inherent ability of a given system design that permits major modification to be performed on the system without degradation in its overall performance during the period of change. The changes could be either by a smooth and gradual phasing in of new or modified equipment or by phasing out old equipment. This MOE treats the inherent capability of a system to be modified either by the upgrading of existing equipment or the replacement of these equipments with new items without its overall performance being degraded. Conversely, the performance should be expected to improve for each change. The approach that should be followed in assessing this MOE is to postulate an equipment change and estimate the resultant system performance. Since the performance figure of merit is a composite of the evaluation of all other MOEs, the analysis of the ease of transition could require a total effectiveness analysis for each change in the system [Ref 10:p.81].

C. MEASURING THE FIGURE OF MERIT FOR SAT/FO

The first step in obtaining a FOM is to establish relative weights for the MOEs in the evaluation. A logical approach to achieving this task is to first rank the MOEs by importance and assign the most important a weight of 10. The next step involves assigning values between 0 and 10 to the remaining MOEs in accordance with their relative weight with respect to the most important [Ref. 10: p. 36].

The next step in obtaining a FOM is to assign utilities to the MOE assessments. A utility is a dimensionless number. The utility will reflect the relative performance of an alternative with respect to a baseline alternative that can be chosen as the middle ranking alternative with respect to one MOE. TRI-TAC utility assignment criteria as shown in Table 12 may be used for satellite and fiber optic system.

To use Table 12 to assign utilities, the following procedure can be employed:

TABLE 12

UTILITY ASSIGNMENT CRITERIA

utility	criteria
0 - 2	Barely meets minimum essential requirements
2 - 4	Less effective than the baseline
5	Baseline
6 - 8	More effective than the baseline
9 -10	More effective to the extent that the MOE should be a principal consideration in the selection of a preferred alternative

- Rank alternatives in accordance with their relative performance under the MOE.
- Assign the median alternative a utility of 5; this becomes the baseline alternative.
- Assign utilities to the remaining alternatives in accordance with the Table 12.

The utilities assigned should reflect the relative effectiveness of each of the alternatives with respect to the baseline. This process is carried out separately for each of the MOEs selected for comparing alternatives. Following this procedure, assessment can be converted into a numerical index of performance that reflects the relative performance of each alternative under the MOE [Ref 10:p.35].

The last step in obtaining a FOM is to combine the weighting and utility information using the formula shown on page 23.

V. COST-EFFECTIVENESS ANALYSIS

A. INTRODUCTION

Cost-Effectiveness analysis is a combined concept of cost and effectiveness as described in Chapter Two. This Chapter will provide a demonstration of Korean International communication alternative selection using a cost-effectiveness methodology. The methodology will illustrate how the analyst or decision maker can select the optimal alternative by using cost-effectiveness methodology.

Data dealing with the cost and effectiveness of satellite and fiber optic systems is very limited and difficult to use. Much of the available data is in the wrong format or there are differences in definitions of categories. The data available is found in "Satellite provided customer premises services", "Unmanned spacecraft cost model", and "Fiber and Integrated Optics" in the reference list. It also is hard to use the available data directly since the economic and technology factors are changing rapidly. These data problems result in uncertainty. Therefore, an extensive sensitivity analysis is included to explore the effects of the data uncertainty.

There are four alternatives that Korea may consider for their international and domestic communication network problems solution. Figure 5.1 shows the four different alternatives in terms of these technological composition and timing considerations. Basically, there are two communication medias to solve the long distance communication problems: satellite and fiber optic cable. The four alternatives consist of a composition of the two basic communication alternatives. Each has a domestic and international component. Referring to Figure 5.1, alternative one uses satellites for both domestic and international areas. Korean domestic satellite communications are planned to the year 2000 by the government [Ref. 12: p. 668]. International satellite communication is now offered by INTELSAT which is leased from the International Telecommunications Satellite Organization [Ref. 13: p.36]. Leasing INTELSAT is economically more attractive than launching a Korean satellite. Alternative two is a combination of fiber optic cable and satellite. The domestic fiber optic network will be used starting in 1988 in limited capacity and general purpose users services will be started in 1993 [Ref. 14: p.107]. Alternative three is completely

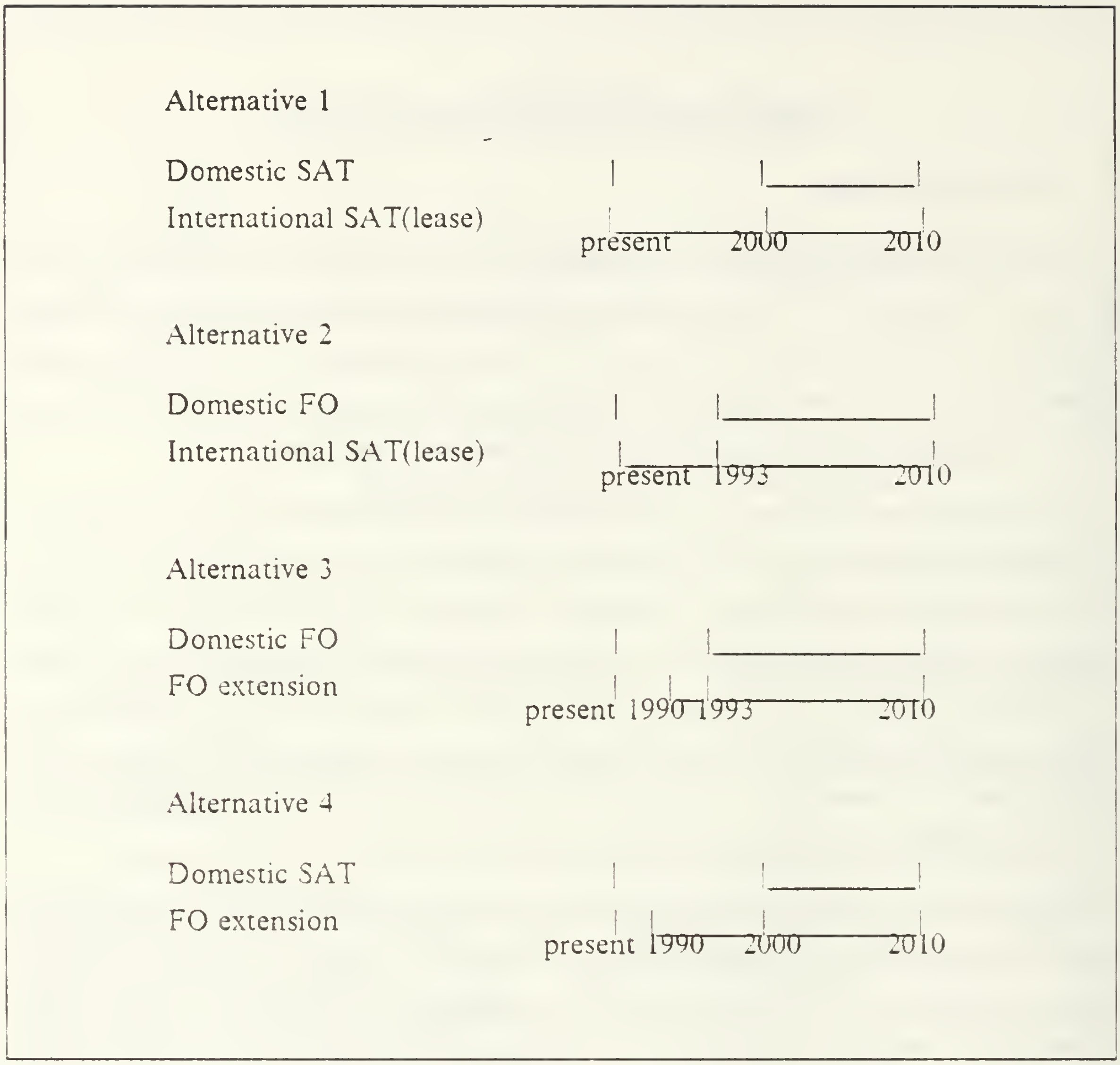

Figure 5.1 Alternatives.

fiber optic, both for domestic and international service. The domestic fiber optic alternative will be the same as in alternative two, but international fiber optic construction will be finished in 1988 between US and Japan via Guam. [Ref. 15: p.20]. This submarine fiber optic cable construction will affect Korean international network planning because the transpacific network will be available if the Korea and Japan extension is completed. Present submarine copper cable with limited capacity should be changed to new large capacity fiber optic cable in the author's opinion. The construction should be followed by the construction of the TPC-3 cable [Ref. 1: p. 33].

Alternative four is a combination of domestic satellite and a fiber optic extension. These alternatives are based on the information available in the literature. The rapid change of the technology brings change in the future environment and the expected year of initial operation may change significantly.

B. COST ANALYSIS

1. Alternative 1

Costs of the first alternative are presented in Table 13. They consist of domestic satellite costs and international satellite lease costs. The Table 13 is based on the following assumptions and equations:

- All units are million dollars except where indicated
- Investment costs are calculated using the model discussed in Chapter Three.

$$
\begin{aligned}
I_t &= I_e + I_s \\
&= 1.4 I_1 + N * [R + L + IN + OH] + S \\
&= 1.4 * 0.964 + 2 * [30 + 30 + 9 + 9] + 45 \\
&= 202.349 * 1.514 (\text{inflation sum until } 1998) \\
&= 306.356
\end{aligned}
$$

- The investment cost will be invested over a period of two years in preparation for operation of the system. Exactly how this investment will spread out over this time is not known so it is assumed to be allocated uniformly over this period.
- International satellite lease costs are calculated from 1987 - 2000 based on traffic forecasting and cost per circuit [Ref. 4: p. 36]. Beyond 2000, costs averaged over the period from present to 1999 are used.
- The discount rate is r = 10% [Ref. 16: p. 460].
- The net present value of all costs(including the opportunity cost for delay) is

  $$NPV = PV * [1 + \rho]^d$$

  A ρ is the delay opportunity cost factor. It is a way to incorporate the lost communication opportunities;i.e. having to wait longer for a communication system alternative is less desirable than not having to wait for one "to come on line". A "d" is delayed years compared to another alternative. The year 1993 is assumed as the 0 delayed year since both domestic and international medias are available simultaneously.

The bottom line of this alternative net present value sum is:

TABLE 13

ALTERNATIVE 1

year	Investment		O&S		Discount	Discounted
	DSAT	ISAT	DSAT	ISAT	Rate	Cost
1987		16.373			1	16.3730
1988		14.686			0.9091	13.3510
1989		13.015			0.8264	10.7556
1990		17.000			0.7513	12.7721
1991		17.303			0.6830	11.8179
1992		15.587			0.6209	9.6780
1993		14.157			0.5645	7.9916
1994		12.756			0.5132	6.5464
1995		19.344			0.4665	9.0240
1996		20.198			0.4241	8.5660
1997		18.312			0.3855	7.0593
1998	153.178	16.592			0.3505	59.5044
1999	153.178	15.093			0.3186	53.6111
2000		24.270	1.514		0.2897	7.4696
2001		16.763	1.514		0.2633	4.8123
2002		16.763	1.514		0.2394	4.3755
2003		16.763	1.514		0.2176	3.9771
2004		16.763	1.514		0.1978	3.6152
2005		16.763	1.514		0.1799	3.2880
2006		16.763	1.514		0.1635	2.9883
2007		16.763	1.514		0.1486	2.7160
2008		16.763	1.514		0.1351	2.4692
2009		16.763	1.514		0.1228	2.2444
						265.006

$$NPV = 265.006 * [\ 1.0 + 0.05\ ]^7$$
$$= 372.890$$

2. Alternative 2

The second alternative is a combination of domestic fiber optic cable and international satellite lease and its costs are presented in Table 14. Domestic fiber optic investment costs are calculated by using Table 9:

$$I_f = C_t + C_r + C_c$$

$$C_t = C_{tm} + C_{fa} + C_{ps} + C_{ts} + C_{im}$$
$$= 29 + 8 + 16 + 28 + 34 = 115$$

$$C_r = C_{rl} + C_{cb} + C_{en} + C_{in}$$
$$= 32 + 1.5 + 3.5 + 13 = 60$$

Cc:

Material	3.8 * 1500 = 5700
Installation	
Large city(10%)	10.0 * 1500 * 0.1 = 1500
Suburbs(40%)	7.0 * 1500 * 0.4 = 4200
Rural(50%)	3.0 * 1500 * 0.5 = 6750

	18,150(K$)

$$I_f = 115 + 60 + 18.15$$
$$= 193.15 * 1.212 \text{ (inflation factor)}$$
$$= 234.098$$

This investment cost will be spread out over three years. Domestic fiber optic O&S cost data are from the final report, "Satellite provided customer premises services," prepared by Western Union telegraph Co, page 122. The bottom line of this alternative's net present value is:

$$NPV = 325.428 * [1.0 + 0.05]^0$$
$$= 325.428$$

TABLE 14

ALTERNATIVE 2

year	Investment		O&S		Discount	Discounted
	DFO	ISAT	DFO	ISAT	Rate	Cost
1987		16.373			1	16.3730
1988		14.686			0.9091	13.3510
1989		13.015			0.8264	10.7556
1990	78.033	17.000			0.7513	71.3983
1991	78.033	17.303			0.6830	65.1145
1992	78.033	15.587			0.6209	58.1286
1993		14.157	1.105		0.5645	8.6154
1994		12.756	1.105		0.5132	7.1135
1995		19.344	1.105		0.4665	9.5395
1996		20.198	1.105		0.4241	9.0346
1997		18.312	1.105		0.3855	7.4852
1998		16.592	1.105		0.3505	6.2028
1999		15.093	1.105		0.3186	5.1607
2000		24.270	1.105		0.2897	7.3511
2001		16.763	1.105		0.2633	4.7046
2002		16.763	1.105		0.2394	4.2776
2003		16.763	1.105		0.2176	3.8881
2004		16.763	1.105		0.1978	3.5343
2005		16.763	1.105		0.1799	3.2144
2006		16.763	1.105		0.1635	2.9214
2007		16.763	1.105		0.1486	2.6552
2008		16.763	1.105		0.1351	2.4140
2009		16.763	1.105		0.1228	2.1942
						325.428

3. Alternative 3

The third alternative consists of domestic a fiber optic system with a fiber optic cable extension between Korea and Japan(110miles). After the transpacific fiber optic submarine cable construction is completed, Korea can be connected to the TPC-3 fiber optic network. Fiber optic extension costs are calculated by using Table 10 and are shown in Table 15.

$$C_f = 2C_c + 2C_r + C_t + 0.7C_i$$
$$= 2 * 2.6 + 2 * 7.8 + 6 + 0.7 * 10$$
$$= 211.13$$

This investment cost will be invested over two years(1988 - 1989). O&S cost will be 1.161 million dollars per year [Ref. 6: p. 60]. Net present value of this alternative is:

$$NPV = 357.262 * [1.0 + 0.05]^0$$
$$= 357.262$$

4. Alternative 4

The fourth alternative is a combination of domestic satellite and the fiber optic extension between Korea and Japan(Table 16). The costs are already calculated in previous alternatives. Net present value of this alternative is:

$$NPV = 296.841 * [1.0 + 0.05]^7$$
$$= 417.685$$

C. EFFECTIVENESS ANALYSIS

To calculate the figure of merit for each alternative, five MOE elements were chosen from Chapter 4. Before these MOE elements can be calculated, however, it requires a major evaluation effort based on detailed technical analysis. Such a level of effort is beyond the scope of this thesis and an alternate evaluation approach is taken. For this thesis, effectiveness measures will be assigned using a subjectively evaluated index. Scaling for each index is from 0 to 10. Table 12 shows the index assignment interpretations created by the author. A baseline value of five is the standard value for this thesis. Based on this number, utility will be assigned by comparing the standard value to satellite and fiber optic performance characteristics.

The transmission capacity for fiber optic systems is currently between 45Mbps and 400Mbps. The Korean communication network is assumed to be 90Mbps for the

TABLE 15

ALTERNATIVE 3

year	Investment		O&S		Discount	Discounted
	DFO	FOX	DFO	FOX	Rate	Cost
1987					1	
1988		105.57			0.9091	95.9737
1989		105.57			0.8264	87.2430
1990	78.033			1.161	0.7513	59.4984
1991	78.033			1.161	0.6830	54.0895
1992	78.033			1.161	0.6209	49.1715
1993			1.105	1.161	0.5645	1.2792
1994			1.105	1.161	0.5132	1.1629
1995			1.105	1.161	0.4665	1.0571
1996			1.105	1.161	0.4241	0.9610
1997			1.105	1.161	0.3855	0.8735
1998			1.105	1.161	0.3505	0.7942
1999			1.105	1.161	0.3186	0.7219
2000			1.105	1.161	0.2897	0.6565
2001			1.105	1.161	0.2633	0.5966
2002			1.105	1.161	0.2394	0.5425
2003			1.105	1.161	0.2176	0.4931
2004			1.105	1.161	0.1978	0.4482
2005			1.105	1.161	0.1799	0.4077
2006			1.105	1.161	0.1635	0.3705
2007			1.105	1.161	0.1486	0.3367
2008			1.105	1.161	0.1351	0.3061
2009			1.105	1.161	0.1228	0.2783
						357.262

TABLE 16

ALTERNATIVE 4

year	Investment		O&S		Discount	Discounted
	DSAT	FOX	DSAT	FOX	Rate	Cost
1987					1	
1988		105.57			0.9010	95.9737
1989		105.57			0.8264	87.2430
1990				1.161	0.7513	0.8723
1991				1.161	0.6830	0.7930
1992				1.161	0.6209	0.7209
1993				1.161	0.5645	0.6554
1994				1.161	0.5132	0.5958
1995				1.161	0.4665	0.5416
1996				1.161	0.4241	0.4924
1997				1.161	0.3855	0.4476
1998	153.178			1.161	0.3505	54.0958
1999	153.178			1.161	0.3186	49.1724
2000			1.514	1.161	0.2897	0.7749
2001			1.514	1.161	0.2633	0.7043
2002			1.514	1.161	0.2394	0.6404
2003			1.514	1.161	0.2176	0.5821
2004			1.514	1.161	0.1978	0.5291
2005			1.514	1.161	0.1799	0.4812
2006			1.514	1.161	0.1635	0.4374
2007			1.514	1.161	0.1486	0.3975
2008			1.514	1.161	0.1351	0.3614
2009			1.514	1.161	0.1228	0.3285
						296.841

inland network and 280Mbps for submarine cable. On the other hand, a typical C-band satellite transponder transmits 60 Mbps. GOS utility numbers are assigned values of six and eight, respectively. The fiber optic bandwidth depends strongly on the spectral width of the source, but a 5Ghz signal can be transmitted a distance 10Km without excessive distortion. Satellite bandwidth for typical C-band is 1.352Ghz. Since the information quality depends on the effective bandwidth for the system, the fiber optic bandwidth will be more effective than the satellite bandwidth. Speed of service is determined by the message queuing time in the network. Since the fiber optic transmission capacity is higher than the satellites, a higher utility number is assigned to the fiber optic system. Satellite MTTR will be very high without using a ground spare. The ease of transition for the two media is considered equal for the next 10 years because the technology in this area appears very competitive and uncertain.

TABLE 17
UTILITY ASSIGNMENT

MOE	SAT	FO	ALT1	ALT2	ALT3	ALT4
GOS(capacity)	6	8	6	7	8	7
IQ(bandwidth)	5	9	5	7	9	7
SOS(queuing)	5	7	5	6	7	6
IOA(MTTR)	3	5	3	4	5	4
EOT(change)	5	5	5	5	5	5

Table 17 shows the utility assignments. Satellite and fiber optic utilities are the left two columns of the Table as discussed above. Those two numbers will be averaged when each alternative utility number is calculated. For example, alternative one consists of domestic satellite and international satellite. Satellite utility six is added and divided by two to get the average number. Thus, the GOS of the first alternative is assigned a six.

Table 18 shows the weighted MOEs and alternative utilities. The weights are ranked by importance, the most important assigned a weight of 10.
For each alternative, FOMs are as follows:

TABLE 18

UTILITY WITH MOE WEIGHT

MOE	weight	ALT1	ALT2	ALT3	ALT4
GOS	10	6	7	8	7
IQ	8	5	7	9	7
SOS	6	5	6	7	6
IOA	4	3	4	5	4
EOT	2	5	5	5	5
FOM (overall)		5.1	6.3	7.5	6.3

$$FOM_{alt1} = \frac{(10*6)+(8*5)+(6*5)+(4*3)+(2*5)}{30} = 5.1$$

$$FOM_{alt2} = \frac{(10*7)+(8*7)+(6*6)+(4*4)+(2*5)}{30} = 6.3$$

$$FOM_{alt3} = \frac{(10*8)+(8*9)+(6*7)+(4*5)+(2*5)}{30} = 7.5$$

$$FOM_{alt4} = \frac{(10*7)+(8*7)+(6*6)+(4*4)+(2*5)}{30} = 6.3$$

D. COST-EFFECTIVENESS RESULTS

Table 19 summarizes the alternatives cost and effectiveness level. The cost unit is changed in 100 million dollars to make the calculations easy. Finally, cost-effectiveness evaluation results are expressed as cost per unit effectiveness level. In this particular case, alternative three is superior to the other alternatives since it has the lowest cost per unit of effectiveness. The preference order is 3, 2, 4 and 1.

The criteria of this thesis evaluation is that "minimize the cost" with subject to effectiveness greater than standard effectiveness. Thus, cost will be fixed at a certain level of budget constraints to choose the best alternative.

TABLE 19

EVALUATION RESULTS

Alternative	cost (100MS)	effectiveness level	cost-effectiveness
1	3.729	5.1	0.731
2	3.254	6.3	0.517
3	3.573	7.5	0.476
4	4.177	6.3	0.663

E. SENSITIVITY ANALYSIS

1. Sources of Uncertainty

There is always uncertainty about the future and the analysis illustrated in this thesis has several sources of uncertainty. First, the cost data used is estimated. Second, the evaluations were subjective because of the MOE values are subjective. Third, the discount rate and opportunity delay inflator may be in error. Since all estimates are subject to some amount of uncertainty, a sensitivity test is helpful in analyzing the alternatives. Thus, if one particular element can be varied over a wide range of values without affecting the decision, the decision under consideration is said to be insensitive to uncertainties regarding that particular factor. The application of the sensitivity concept becomes an intermediate step between the numerical analysis based on the best estimates for the various elements and the final decision. Each factor can be tested to see how sensitive the decision is to variations in the factor's data. It is also very useful to identify the most important factors in the analysis,i.e. where a great deal of high quality information and data is required.

The Table 19 evaluation results were calculated using uncertain data, both in the cost and effectiveness measures. To assess the effect of these uncertainties four related factors will be tested:

- Cost estimate sensitivity; repeat with all fiber optic costs increased by 20%,

- MOE sensitivity; increase satellite MOE by 1 and decrease fiber optic MOE by 1, then increase satellite MOE by 2 and decrease fiber optic MOE by 2,
- Discount rate sensitivity; recompute cost-effectiveness with r = 0.06, 0.08, 0.1, 0.15, 0.18,
- Delay opportunity cost factor(inflator) sensitivity; recompute cost-effectiveness with ρ = 0, 0.03, 0.05, 0.10, 0.15.

2. Cost Estimate Sensitivity

When all fiber optic costs were increased by 20%, all alternative costs change except alternative one. Detailed costs are in the Appendix C. Table 20 shows the cost-effectiveness results. The cost is inflated by 0.2. The preference ordering changes to 2, 3, 1 and 4.

TABLE 20

CHANGED COST EVALUATION RESULTS

Alternative	cost (100M$)	effectiveness level	cost-effectiveness
1	3.729	5.1	0.731
2	3.586	6.3	0.569
3	4.287	7.5	0.572
4	4.715	6.3	0.748

This means if the fiber optic costs increase more than 20%, the highest cost-effectiveness value moves from alternative three to alternative two, but note that alternative two only drops one position in the ordering, in other words alternative two and three just changed positions.

3. Discount Rate and Delay Opportunity Cost Factor Sensitivity

Table 21 lists the results of calculations in changing the discount rate with ρ = 0.

Appendix A shows the Tables which are calculated by using ρ = 0, 0.03, 0.05, 0.10, and 0.15. Notice the new order of preference , alternative three has the highest

TABLE 21

CHANGE DISCOUNT RATE (ρ = 0)

1.Cost(100mS)

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	4.593	4.677	4.250	4.166
6	3.777	4.096	3.997	3.678
8	3.145	3.632	3.773	3.286
10	2.650	3.254	3.573	2.968
15	1.816	2.567	3.152	2.401
18	1.494	2.270	2.941	2.165

2.Effectiveness

Level	5.1	6.3	7.5	6.3

3.Cost-Effectiveness

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	0.901	0.742	0.567*	0.661
6	0.741	0.650	0.533*	0.584
8	0.616	0.577	0.503*	0.522
10	0.520	0.517	0.476	0.471*
15	0.356*	0.407	0.420	0.381
18	0.293*	0.360	0.392	0.344

preference for r = 0.04 to 0.1 . On the other hand alternative two is the best for r = 0.15, and 0.18.

4. MOE Sensitivity

The MOE sensitivity is checked by changing the utility values. First, the MOE utilities are changed by adding by 1 to the satellite MOE's and subtracting 1 from the fiber optic MOE's. Second, the utilities are changed by adding and subtracting by 2. Table 22 shows the first utility change. In this way a measure of how much the effectiveness evaluations may be biased in favor of the satellite system may be obtained. It is recalculated the same way as on page 61.

TABLE 22

UTILITY CHANGE 1

MOE	SAT	FO	ALT1	ALT2	ALT3	ALT4
GOS	7	7	7	7	7	7
IQ	6	8	6	7	8	7
SOS	6	6	6	6	6	6
IOA	4	4	4	4	4	4
EOT	6	4	6	5	4	5
FOM			6.1	6.3	6.5	6.3

$$FOM_{alt1} = \frac{(10*7)+(8*6)+(6*6)+(4*4)+(2*6)}{30} = 6.1$$

$$FOM_{alt2} = \frac{(10*7)+(8*7)+(6*6)+(4*4)+(2*5)}{30} = 6.3$$

$$FOM_{alt3} = \frac{(10*7)+(8*8)+(6*6)+(4*4)+(2*4)}{30} = 6.5$$

$$FOM_{alt4} = \frac{(10*7)+(8*7)+(6*6)+(4*4)+(2*5)}{30} = 6.3$$

Table 23 shows the effects of the second change.

TABLE 23
UTILITY CHANGE 2

MOE	SAT	FO	ALT1	ALT2	ALT3	ALT4
GOS	8	6	8	7	6	7
IQ	7	7	7	7	7	7
SOS	7	5	7	6	5	6
IOA	5	3	5	4	3	4
EOT	7	3	7	5	3	5
FOM			7.1	6.3	5.5	6.3

The results of the different utility changes are in the Appendix B and C. The first change results are alternative two being the highest order of preference and alternative three the next. The second change places the highest order of preference on alternative one. It should be noted, however, that to get this result the MOE's had to be biased strongly in favor of the satellite system. Thus, the fiber optic cable dominates whenever the effectiveness measures of the satellite system are not more superior than one index point. This means that the satellite system is attractive only if it is technologically markedly superior.

5. Summary

Table 24 summarizes the results of the changed values which include all the calculations in terms of the order of preferences. Detailed Tables are in Appendix D. The number in parentheses denotes the total count for how many times the alternative was ranked most preferred. The number below the parentheses gives the overall ranking of the alternative, based on this count. For example, alternative three was ranked most preferred eighteen out of thirty times during the sensitivity study of r and ρ. In the author's opinion a useful way to choose alternative in such a situation is to choose the alternative that is most frequently reached as number one. Thus alternative

three is most preferred overall. On the other hand, alternative four ranked first in only one case during this study, and thus ranks last overall.

TABLE 24
SUMMARY OF RESULTS

	ALT 1	ALT 2	ALT 3	ALT 4
Initial	(2) 3	(9) 2	(18) 1	(1) 4
1st change	(7) 3	(13) 1	(9) 2	(1) 4
2nd change	(11) 1	(10) 2	(6) 3	(3) 4
overall	3	2	1	4

There is another way to find the best alternative. As seen in Appendices A, B and C, an alternative's preference changes with respect to r, ρ and MOE. To understand the alternative that has the minimum cost per unit effectiveness, see Figure 5.2. It shows how the cost-effectiveness values depend on r. The order of preference can be seen by tracking the lowest lines which represent minimum cost per unit effectiveness.

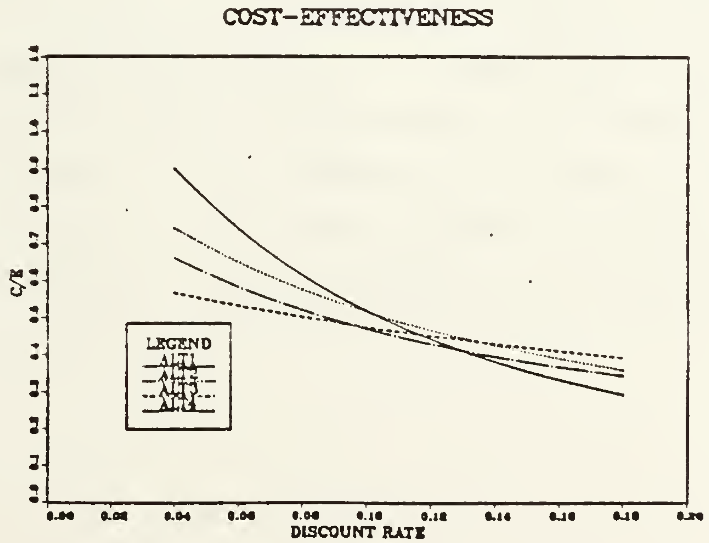

Figure 5.2 Alternative Selection.

The best alternative changes at the crosspoints. This Figure is based on the initial MOE and $\rho = 0.05$.

VI. CONCLUSIONS

A. FINDINGS

The greatest difficulty in this study was gathering data. Sensitivity analysis is suggested as a means of dealing with these data uncertainties. The findings of the sensitivity test are:

- Using the baseline case the most attractive alternative is alternative three, but alternative two is not too far away in terms of its C/E ratio; this means that there should be some fiber optic component in any communication system.
- When fiber optic costs are increased by 20% alternative two is preferred.
- Alternative one and four are inferior alternatives. The delay time cost dominates for these alternatives. Clearly, it is important to consider the time cost if the planning dates between alternative are different.

B. CONCLUSIONS

This thesis presents a methodology for the cost-effectiveness analysis of several Korean international communication alternatives. The study was intended as an initial approach for Korean domestic and international communication alternatives with consideration of satellite and fiber optic transmission media. The historical background of Korean communication development was discussed and a cost-effectiveness model was developed for each media. The cost model was developed by using a cost break-down structure. The effectiveness model was adapted from the concepts introduced in the TRI-TAC system effectiveness model. The model's application to a Korean communication network is presented. Four alternatives were discussed for satellite and fiber optic cable systems. The final conclusion is that alternative three is the most preferable selection for Korea in the author's opinion. However, alternative two is close in terms of the C/E ratio. Using the sensitivity tests, fiber optic costs can not increase by more than 20% otherwise the preference for alternative two or three changes.

C. RECOMMENDATIONS

The author recommends that another study similar to this one be undertaken to evaluate the fiber optic cable and satellite cost-effectiveness models for consideration in improving Korean international communications. Specifically, system effectiveness analysis using performance evaluations should be undertaken to develop a more realistic effectiveness model.

To improve the Korean international communication network, alternatives should be considered that include fiber optic cables in conjunction with a satellite system.

APPENDIX A
CHANGE DISCOUNT RATE AND ρ

TABLE 25
CHANGE DISCOUNT RATE ($\rho = 0$)

1.Cost(100m$)

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	4.593	4.677	4.250	4.166
6	3.777	4.096	3.997	3.678
8	3.145	3.632	3.773	3.286
10	2.650	3.254	3.573	2.968
15	1.816	2.567	3.152	2.401
18	1.494	2.270	2.941	2.165

2.Effectiveness

Level	5.1	6.3	7.5	6.3

3.Cost-Effectiveness

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	0.901	0.742	0.567*	0.661
6	0.741	0.650	0.533*	0.584
8	0.616	0.577	0.503*	0.522
10	0.520	0.517	0.476	0.471*
15	0.356*	0.407	0.420	0.381
18	0.293*	0.360	0.392	0.344

TABLE 26

CHANGE DISCOUNT RATE (ρ = 0.03)

1.Cost(100mS)

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	5.649	4.677	4.250	5.124
6	4.645	4.096	3.977	4.524
8	3.868	3.632	3.773	4.041
10	3.259	3.254	3.573	3.650
15	2.233	2.567	3.152	2.953
18	1.837	2.270	2.941	2.663

2.Effectiveness

Level	5.1	6.3	7.5	6.3

3.Cost-Effectiveness

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	1.108	0.742	0.567*	0.813
6	0.911	0.650	0.533*	0.718
8	0.758	0.577	0.503*	0.641
10	0.639	0.517	0.476*	0.579
15	0.438	0.407*	0.420	0.469
18	0.360	0.360*	0.392	0.423

TABLE 27

CHANGE DISCOUNT RATE (ρ = 0.05)

1.Cost(100m$)

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	6.463	4.677	4.250	5.862
6	5.315	4.096	3.977	5.175
8	4.425	3.632	3.773	4.624
10	3.729	3.254	3.573	4.176
15	2.555	2.567	3.152	3.378
18	2.102	2.270	2.941	3.046

2.Effectiveness

Level	5.1	6.3	7.5	6.3

3.Cost-Effectiveness

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	1.267	0.742	0.567*	0.930
6	1.042	0.650	0.533*	0.821
8	0.868	0.577	0.503*	0.734
10	0.731	0.517	0.476*	0.663
15	0.501	0.407*	0.420	0.536
18	0.412	0.360*	0.392	0.483

TABLE 28

CHANGE DISCOUNT RATE (ρ = 0.10)

1.Cost(100mS)

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	8.950	4.677	4.250	8.118
6	7.360	4.096	3.977	7.167
8	6.129	3.632	3.773	6.403
10	5.164	3.254	3.573	5.784
15	3.539	2.567	3.152	4.679
18	2.911	2.270	2.941	4.219

2.Effectiveness

Level	5.1	6.3	7.5	6.3

3.Cost-Effectiveness

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	1.755	0.742	0.567*	1.286
6	1.443	0.650	0.533*	1.138
8	1.202	0.577	0.503*	1.016
10	1.013	0.517	0.476*	0.918
15	0.694	0.407*	0.420	0.743
18	0.571	0.360*	0.392	0.670

TABLE 29

CHANGE DISCOUNT RATE ($\rho = 0.15$)

1.Cost(100mS)

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	12.217	4.677	4.250	11.082
6	10.047	4.096	3.977	9.783
8	8.366	3.632	3.773	8.741
10	7.049	3.254	3.573	7.895
15	4.831	2.567	3.152	6.387
18	3.974	2.270	2.941	5.759

2.Effectiveness

Level	5.1	6.3	7.5	6.3

3.Cost-Effectiveness

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	2.395	0.742	0.567*	1.759
6	1.970	0.650	0.533*	1.553
8	1.640	0.577	0.503*	1.387
10	1.382	0.517	0.476*	1.253
15	0.947	0.407*	0.420	1.014
18	0.779	0.360*	0.392	0.914

APPENDIX B
CHANGE MOE LEVEL 1 (ρ = 0 - 0.15)

TABLE 30

CHANGE MOE LEVEL 1(ρ = 0)

1.Cost(100mS)

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	4.593	4.677	4.250	4.166
6	3.777	4.096	3.997	3.678
8	3.145	3.632	3.773	3.286
10	2.650	3.254	3.573	2.968
15	1.816	2.567	3.152	2.401
18	1.494	2.270	2.941	2.165

2.Effectiveness

Level	6.1	6.3	6.5	6.3

3.Cost-Effectiveness

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	0.753	0.742	0.654*	0.661
6	0.619	0.650	0.612	0.584*
8	0.515*	0.577	0.580	0.522
10	0.434*	0.517	0.550	0.471
15	0.298*	0.407	0.485	0.381
18	0.245*	0.360	0.452	0.344

TABLE 31

CHANGE MOE LEVEL 1(ρ = 0.03)

1.Cost(100mS)

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	5.649	4.677	4.250	5.124
6	4.645	4.096	3.977	4.524
8	3.868	3.632	3.773	4.041
10	3.259	3.254	3.573	3.650
15	2.233	2.567	3.152	2.953
18	1.837	2.270	2.941	2.663

2.Effectiveness

Level	6.1	6.3	6.5	6.3

3.Cost-Effectiveness

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	0.926	0.742	0.654*	0.813
6	0.761	0.650	0.615*	0.718
8	0.634	0.577*	0.580	0.641
10	0.534	0.517*	0.550	0.579
15	0.366*	0.407	0.485	0.469
18	0.301*	0.360	0.452	0.423

TABLE 32
CHANGE MOE LEVEL 1(ρ = 0.05)

1.Cost(100mS)

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	6.463	4.677	4.250	5.862
6	5.315	4.096	3.977	5.175
8	4.425	3.632	3.773	4.624
10	3.729	3.254	3.573	4.176
15	2.555	2.567	3.152	3.378
18	2.102	2.270	2.941	3.046

2.Effectiveness

Level	6.1	6.3	6.5	6.3

3.Cost-Effectiveness

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	1.060	0.742	0.654*	0.930
6	0.871	0.650	0.615*	0.821
8	0.725	0.577*	0.580	0.734
10	0.611	0.517*	0.550	0.663
15	0.419	0.407*	0.485	0.536
18	0.345*	0.360	0.452	0.483

TABLE 33

CHANGE MOE LEVEL 1(ρ = 0.10)

1.Cost(100m$)

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	8.950	4.677	4.250	8.118
6	7.360	4.096	3.977	7.167
8	6.129	3.632	3.773	6.403
10	5.164	3.254	3.573	5.784
15	3.539	2.567	3.152	4.679
18	2.911	2.270	2.941	4.219

2.Effectiveness

Level	6.1	6.3	6.5	6.3

3.Cost-Effectiveness

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	1.467	0.742	0.654*	1.286
6	1.207	0.650	0.612*	1.138
8	1.005	0.577*	0.580	1.016
10	0.847	0.517*	0.550	0.918
15	0.580	0.407*	0.485	0.743
18	0.477	0.360*	0.452	0.670

TABLE 34

CHANGE MOE LEVEL 1(ρ = 0.15)

1.Cost(100mS)

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	12.217	4.677	4.250	11.082
6	10.047	4.096	3.977	9.783
8	8.366	3.632	3.773	8.741
10	7.049	3.254	3.573	7.895
15	4.831	2.567	3.152	6.387
18	3.974	2.270	2.941	5.759

2.Effectiveness

Level	6.1	6.3	6.5	6.3

3.Cost-Effectiveness

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	2.003	0.742	0.654*	1.759
6	1.647	0.650	0.615*	1.553
8	1.371	0.577*	0.580	1.387
10	1.156	0.517*	0.550	1.253
15	0.792	0.407*	0.485	1.014
18	0.651	0.360*	0.452	0.914

APPENDIX C
CHANGE MOE LEVEL 2 (ρ = 0 - 0.15) AND INCREASED FO COST

TABLE 35
CHANGE MOE LEVEL 2 (ρ = 0)

1.Cost(100mS)

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	4.593	4.677	4.250	4.166
6	3.777	4.096	3.997	3.678
8	3.145	3.632	3.773	3.286
10	2.650	3.254	3.573	2.968
15	1.816	2.567	3.152	2.401
18	1.494	2.270	2.941	2.165

2.Effectiveness

Level	7.1	6.3	5.5	6.3

3.Cost-Effectiveness

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	0.647*	0.742	0.773	0.661
6	0.532*	0.650	0.726	0.584
8	0.443*	0.577	0.686	0.522
10	0.373*	0.517	0.650	0.471
15	0.256*	0.407	0.573	0.381
18	0.210*	0.360	0.535	0.344

TABLE 36

CHANGE MOE LEVEL 2(ρ = 0.03)

1.Cost(100mS)

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	4.593	4.677	4.250	4.166
6	3.777	4.096	3.997	3.678
8	3.145	3.632	3.773	3.286
10	2.650	3.254	3.573	2.968
15	1.816	2.567	3.152	2.401
18	1.494	2.270	2.941	2.165

2.Effectiveness

Level	7.1	6.3	5.5	6.3

3.Cost-Effectiveness

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	0.796	0.742	0.773	0.661*
6	0.654	0.650	0.726	0.584*
8	0.545	0.577	0.686	0.522*
10	0.459*	0.517	0.650	0.471
15	0.315*	0.407	0.573	0.381
18	0.259*	0.360	0.535	0.344

TABLE 37

CHANGE MOE LEVEL 2(ρ = 0.05)

1.Cost(100m$)

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	6.463	4.677	4.250	5.862
6	5.315	4.096	3.977	5.175
8	4.425	3.632	3.773	4.624
10	3.729	3.254	3.573	4.176
15	2.555	2.567	3.152	3.378
18	2.102	2.270	2.941	3.046

2.Effectiveness

Level	7.1	6.3	5.5	6.3

3.Cost-Effectiveness

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	0.910	0.742	0.654*	0.930
6	0.749	0.650	0.615*	0.821
8	0.623	0.577*	0.580	0.734
10	0.525	0.517*	0.550	0.663
15	0.360*	0.407	0.485	0.536
18	0.296*	0.360	0.452	0.483

TABLE 38

CHANGE MOE LEVEL 2 (ρ = 0.10)

1.Cost(100mS)

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	8.950	4.677	4.250	8.118
6	7.360	4.096	3.977	7.167
8	6.129	3.632	3.773	6.403
10	5.164	3.254	3.573	5.784
15	3.539	2.567	3.152	4.679
18	2.911	2.270	2.941	4.219

2.Effectiveness

Level	7.1	6.3	5.5	6.3

3.Cost-Effectiveness

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	1.260	0.742	0.654*	1.286
6	1.037	0.650	0.612*	1.138
8	0.863	0.577*	0.580	1.016
10	0.727	0.517*	0.550	0.918
15	0.498	0.407*	0.485	0.743
18	0.410	0.360*	0.452	0.670

TABLE 39

CHANGE MOE LEVEL 2 (ρ = 0.15)

1.Cost(100mS)

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	12.217	4.677	4.250	11.082
6	10.047	4.096	3.977	9.783
8	8.366	3.632	3.773	8.741
10	7.049	3.254	3.573	7.895
15	4.831	2.567	3.152	6.387
18	3.974	2.270	2.941	5.759

2.Effectiveness

Level	7.1	6.3	5.5	6.3

3.Cost-Effectiveness

r(%)	ALT 1	ALT 2	ALT 3	ALT4
4	1.721	0.742	0.654*	1.759
6	1.415	0.650	0.615*	1.553
8	1.178	0.577*	0.580	1.387
10	0.993	0.517*	0.550	1.253
15	0.680	0.407*	0.485	1.014
18	0.560	0.360*	0.452	0.914

TABLE 40

ALTERNATIVE 1(INCREASED FO COST)

year	Investment		O&S		Discount	Discounted
	DSAT	ISAT	DSAT	ISAT	Rate	Cost
1987		16.373			1	16.3730
1988		14.686			0.9091	13.3510
1989		13.015			0.8264	10.7556
1990		17.000			0.7513	12.7721
1991		17.303			0.6830	11.8179
1992		15.587			0.6209	9.6780
1993		14.157			0.5645	7.9916
1994		12.756			0.5132	6.5464
1995		19.344			0.4665	9.0240
1996		20.198			0.4241	8.5660
1997		18.312			0.3855	7.0593
1998	153.178	16.592			0.3505	59.5044
1999	153.178	15.093			0.3186	53.6111
2000		24.270	1.514		0.2897	7.4696
2001		16.763	1.514		0.2633	4.8123
2002		16.763	1.514		0.2394	4.3755
2003		16.763	1.514		0.2176	3.9771
2004		16.763	1.514		0.1978	3.6152
2005		16.763	1.514		0.1799	3.2880
2006		16.763	1.514		0.1635	2.9883
2007		16.763	1.514		0.1486	2.7160
2008		16.763	1.514		0.1351	2.4692
2009		16.763	1.514		0.1228	2.2444
						265.006

TABLE 41

ALTERNATIVE 2(INCREASED FO COST)

year	Investment		O&S		Discount	Discounted
	DFO	ISAT	DFO	ISAT	Rate	Cost
1987	0.0000	16.373	0.000		1.0000	16.3730
1988	0.0000	14.686	0.000		0.9091	13.3510
1989	0.0000	13.015	0.000		0.8264	10.7556
1990	93.6396	17.000	0.000		0.7513	83.1235
1991	93.6396	17.303	0.000		0.6830	75.7738
1992	93.6396	15.587	0.000		0.6209	67.8188
1993	0.0000	14.157	1.326		0.5645	8.7402
1994	0.0000	12.756	1.326		0.5132	7.2269
1995	0.0000	19.344	1.326		0.4665	9.6425
1996	0.0000	20.198	1.326		0.4241	9.1283
1997	0.0000	18.312	1.326		0.3855	7.5704
1998	0.0000	16.592	1.326		0.3505	6.2803
1999	0.0000	15.093	1.326		0.3186	5.2311
2000	0.0000	24.270	1.326		0.2897	7.4152
2001	0.0000	16.763	1.326		0.2633	4.7628
2002	0.0000	16.763	1.326		0.2394	4.3305
2003	0.0000	16.763	1.326		0.2176	3.9362
2004	0.0000	16.763	1.326		0.1978	3.5780
2005	0.0000	16.763	1.326		0.1799	3.2542
2006	0.0000	16.763	1.326		0.1635	2.9575
2007	0.0000	16.763	1.326		0.1486	2.6880
2008	0.0000	16.763	1.326		0.1351	2.4438
2009	0.0000	16.763	1.326		0.1228	2.2213
						358.603

TABLE 42

ALTERNATIVE 3(INCREASED FO COST)

year	Investment		O&S		Discount	Discounted
	DFO	FOX	DFO	FOX	Rate	Cost
1987	0.0000	0.000	0.000	0.0000	1.0000	0.000
1988	0.0000	126.684	0.000	0.0000	0.9091	115.168
1989	0.0000	126.684	0.000	0.0000	0.8264	104.692
1990	93.6396	0.000	0.000	1.3932	0.7513	71.398
1991	93.6396	0.000	0.000	1.3932	0.6830	64.907
1992	93.6396	0.000	0.000	1.3932	0.6209	59.006
1993	0.0000	0.000	1.326	1.3932	0.5645	1.535
1994	0.0000	0.000	1.326	1.3932	0.5132	1.395
1995	0.0000	0.000	1.326	1.3932	0.4665	1.269
1996	0.0000	0.000	1.326	1.3932	0.4241	1.153
1997	0.0000	0.000	1.326	1.3932	0.3855	1.048
1998	0.0000	0.000	1.326	1.3932	0.3505	0.953
1999	0.0000	0.000	1.326	1.3932	0.3186	0.866
2000	0.0000	0.000	1.326	1.3932	0.2897	0.788
2001	0.0000	0.000	1.326	1.3932	0.2633	0.716
2002	0.0000	0.000	1.326	1.3932	0.2394	0.651
2003	0.0000	0.000	1.326	1.3932	0.2176	0.592
2004	0.0000	0.000	1.326	1.3932	0.1978	0.538
2005	0.0000	0.000	1.326	1.3932	0.1799	0.489
2006	0.0000	0.000	1.326	1.3932	0.1635	0.445
2007	0.0000	0.000	1.326	1.3932	0.1486	0.404
2008	0.0000	0.000	1.326	1.3932	0.1351	0.367
2009	0.0000	0.000	1.326	1.3932	0.1228	0.334
						428.714

TABLE 43

ALTERNATIVE 4(INCREASED FO COST)

year	Investment		O&S		Discount	Discounted
	DSAT	FOX	DSAT	FOX	Rate	Cost
1987	0.000	0.000	0.000	0.0000	1.0000	0.000
1988	0.000	126.684	0.000	0.0000	0.9091	115.168
1989	0.000	126.684	0.000	0.0000	0.8264	104.692
1990	0.000	0.000	0.000	1.3932	0.7513	1.047
1991	0.000	0.000	0.000	1.3932	0.6830	0.952
1992	0.000	0.000	0.000	1.3932	0.6209	0.865
1993	0.000	0.000	0.000	1.3932	0.5645	0.786
1994	0.000	0.000	0.000	1.3932	0.5132	0.715
1995	0.000	0.000	0.000	1.3932	0.4665	0.650
1996	0.000	0.000	0.000	1.3932	0.4241	0.591
1997	0.000	0.000	0.000	1.3932	0.3855	0.537
1998	153.178	0.000	0.000	1.3932	0.3505	54.177
1999	153.178	0.000	0.000	1.3932	0.3186	49.246
2000	0.000	0.000	1.514	1.3932	0.2897	0.842
2001	0.000	0.000	1.514	1.3932	0.2633	0.765
2002	0.000	0.000	1.514	1.3932	0.2394	0.696
2003	0.000	0.000	1.514	1.3932	0.2176	0.633
2004	0.000	0.000	1.514	1.3932	0.1978	0.575
2005	0.000	0.000	1.514	1.3932	0.1799	0.523
2006	0.000	0.000	1.514	1.3932	0.1635	0.475
2007	0.000	0.000	1.514	1.3932	0.1486	0.432
2008	0.000	0.000	1.514	1.3932	0.1351	0.393
2009	0.000	0.000	1.514	1.3932	0.1228	0.357
						335.117

APPENDIX D
SUMMARY OF RESULTS

TABLE 44

SUMMARY OF RESULTS

r&.ρ	ALT 1	ALT 2	ALT 3	ALT4
r = 0.04				
ρ = 0	4-4-1*	3-3-3	1-1-4	2-2-2
ρ = 0.03	4-4-4	2-2-2	1-1-3	3-3-1
ρ = 0.05	4-4-3	2-2-2	1-1-1	3-3-4
ρ = 0.10	4-4-3	2-2-2	1-1-1	3-3-4
ρ = 0.15	4-4-3	2-2-2	1-1-1	3-3-4
r = 0.06				
ρ = 0	4-3-1	3-4-3	1-2-4	2-1-2
ρ = 0.03	4-4-3	2-2-2	1-1-4	3-3-1
ρ = 0.05	4-4-3	2-2-2	1-1-1	3-3-4
ρ = 0.10	4-3-3	2-2-2	1-1-1	3-4-4
ρ = 0.15	4-4-3	2-2-2	1-1-1	3-3-4
r = 0.08				
ρ = 0	4-1-1	3-3-3	1-4-4	2-2-2
ρ = 0.03	4-3-2	2-1-3	1-2-4	3-4-1
ρ = 0.05	4-3-3	2-1-1	1-2-2	3-4-4
ρ = 0.10	4-3-3	2-1-1	1-2-2	3-4-4
ρ = 0.15	3-3-3	1-1-1	2-2-2	4-4-4
r = 0.10				
ρ = 0	4-1-1	3-3-3	2-1-4	1-2-2
ρ = 0.03	4-2-1	2-1-3	1-3-4	3-4-2
ρ = 0.05	4-3-2	2-1-1	1-2-3	3-4-4
ρ = 0.10	4-3-3	2-1-1	1-2-2	3-4-4
ρ = 0.15	4-3-3	2-1-1	1-2-2	3-4-4
r = 0.15				
ρ = 0	1-1-1	3-3-3	4-4-4	2-2-2
ρ = 0.03	3-1-1	1-2-3	2-4-4	4-3-2
ρ = 0.05	3-2-1	1-1-2	2-3-3	4-4-4
ρ = 0.10	3-3-3	1-1-1	2-2-2	4-4-4
ρ = 0.15	3-3-3	1-1-1	2-2-2	4-4-4
r = 0.18				
ρ = 0	1-1-1	3-3-3	4-4-4	2-2-2
ρ = 0.03	3-1-1	1-2-3	2-4-4	4-3-2
ρ = 0.05	3-1-1	1-2-2	2-3-3	4-4-4
ρ = 0.10	3-3-2	1-1-1	2-2-3	4-4-4
ρ = 0.15	3-3-3	1-1-1	2-2-2	4-4-4

* () - () - () : Initial - 1st change - 2nd change

APPENDIX E
INTRODUCTION OF US COMMUNICATION SATELLITE

1. DOMESTIC SATCOM SYSTEMS AND CONCEPTS

a. Current Systems

Current(1986) DOD domestic telecommunication capabilities consist of a large number of networks that use military, commercial, dedicated, and non-dedicated(i.e shared) terrestrial and satellite systems. This Appendix E summarizes a part of report in the reference list 15. In this section, existing domestic commercial SATCOM systems are reviewed.

(1) Space Segment

Several domestic commercial SATCOM systems are being used to provide a wide spectrum of communications services. These systems are owned and/or operated by several companies. Typical systems are SATCOM(RCA-Americom), SPACENET(GTE spacenet), Galaxy(Hughes communications,Inc), TELSTAR(AT&T Communication), COMSTAR(COMSAT General), WESTAR(W.U. Telegraph), SBS(Satellite Business Systems), and GSTAR(GTE Satellite). Most of the exiting commercial satellites operate in the C-band, although some operate in the K_u-band, and others are hybrids operating at both frequency bands(SPACENET). However, the number of k_u-band satellite will increase in the future. Typical C-band spacecraft parameters are summarized in the Table 45 below.
All of the systems provide CONUS coverage, and some are capable of providing coverages for Alaska, Hawaii, and Puerto Rico.

(2) Earth Station

The ground segment of the C-band domestic SATCOM generally consists of two types of terminals: trunking terminals that are capable of high throughput capacity and dedicated terminals designed to support a smaller capacity. Typical characteristics of these terminals are summarized in Table 46.
In the Table 46, TDMA and FDMA refer to time and frequency division multiple access, respectively. QPSK refers to quadrature phase shift keying, DPSK refers to differential phase shift keying, and FM refers to frequency modulation.

TABLE 45

TYPICAL C-BAND SAT PARAMETERS

Number of transponders	24
Transponder bandwidth	36Mhz
Transponder EIRP	34dbw
Communications frequency	
Transmit	3.7 - 4.2Ghz
Receive	5.925 -6.425Ghz
Polarization	linear
G/T	-4to-7db/°k

TABLE 46

TYPICAL C-BAND TERMINAL CHARACTERISTICS

characteristic	trunking	dedicated
ANT size(m)	10 - 30	4.5 - 15.5
EIRP(dbw)	80 - 92	45 - 80
G/T(db/°k)	31 - 42	23 - 33
Pointing ability	full	partial to full
Freq agility	most	some
multiple access	TDMA,FDMA	TDMA,FDMA
Modulation	QPSK,DPSK,FM	QPSK

K_u-band dedicated earth terminals, however, are more polarization agile and frequency agile than their C-band counterparts because of their advanced technological systems. The characteristics of typical k_u-band U.S. domestic earth terminals are summarized in Table 47.

(3) Control Segment

Current U.S domestic SATCOM are built by the Hughes and RCA Corporations. Although differences in telemetry, tracking and control(TT&C) systems exist, there are some similarities.

TABLE 47

TYPICAL K_U -BAND TERMINAL CHARACTERISTICS

characteristic	trunking	dedicated
ANT size(m)	7 - 12	1.2 - 5
EIRP(dbw)	80 - 90	50 - 80
G/T(db/°k)	32 - 34	16 - 27
Pointing ability	full	full
Freq agility	most	most
multiple access	TDMA	TDMA,FDMA
Modulation	QPSK	BPSK,QPSK

The command signal transmitted by the TT&C ground station are received and demodulated by the satellite command receiver and then decoded and fed to the control equipment. The command process includes error correction and verification but no encryption. As a protection AT&T employs a "command intrusion detector" that afford some shielding against deliberate spoofing, while American Satellite Corporation plans to use the Data Encryption standards(DES) for its command link in the mid-term. TT&C earth stations are generally 10m or more in size and are typically designed to provide large link margins.

For telemetry, various housekeeping data, showing the overall status of different portions of spacecraft, are multiplexed and coded to modulate a beacon frequency for reception at a TT&C earth station.

All common carriers have a central monitor and control terminal that usually is incorporated at the TT&C sites. The monitor and control terminal consists of monitoring equipment that analyzes the transmission parameters of all participating terminals. Deviations from planned usage are identified, and appropriate actions are taken.

These are orderwires between the M&C site and other terminals. These orderwires can be on separate channels or can be incorporated into the main network communication structure, as is the case in all TDMA networks. The existence of the M&C is essential to satisfactory network operation. It is anticipated that none of these M&C terminals will be operational in post-attack, therefore, if centralized network is to be used, appropriate backup would be needed.

b. Mid-term(1986-1991) Systems

During the 1986 to 1991 time frame many additional spacecraft will be deployed to expand the systems and capabilities presented earlier. Furthermore, the introduction of the several new systems are planned. American satellite company(ASC), U.S. Satellite services Inc, Ford Aerospace Corps, Advanced business Communications, Rainbow Satellite Inc. and Martin Marietta are some of the commercial companies that have planning their own systems.

The majority of new satellites to be introduced in the mid-term are k_u-band satellite, although some C-band spacecraft are planned to replace or complement those already in orbit. The various k_u-band satellites will basically employ existing technologies and will continue to have varying characteristics. These satellites will have 10, 16, 20, 24, and 28 transponders per spacecraft. Some will incorporate higher EIRP levels, ranging from 38-60 dbw.

The large expansion of domestic k_u-band resources in the mid-term is an important consideration. k_u-band systems allow use of smaller earth stations and are not vulnerable to the terrestrial interference experienced at C-band. These systems provide an attractive alternative to C-band in the development of a commercial SATCOM. The existing domestic systems will experience many changes in the mid-term, such as:

- the number of domestic SATCOM systems will increase to accommodate the growth in domestic traffic requirements
- some of these systems will incorporate advanced technologies
- the role of fiber optics will become increasingly important because of the additional capacity fiber optic cables can provide
- the divesture of AT&T will permit new domestic carriers and networks and increased competition.

c. Far-term(1992-2000) Systems

The various C-band and k_u -band systems presented for the current and mid-terms are expected to continue providing domestic SATCOM services over CONUS. Given the 10-year spacecraft design life that is achievable today, the various satellites to be developed during the mid-term are expected to continue their services through the mid-to-late far-term(beyond 1995).

In the far-term, new satellite will replace and expand commercial SATCOM resources. Although specific far-term spacecraft designs and technologies, are expected to emerge.

Far-term commercial SATCOM spacecraft concepts, which are receiving increased attention by private industry, include mobile satellite systems. M-SAT is one example of mobile SATCOM and has been under consideration as a joint Canadian-U.S. effort. M-SATs are envisioned to provide communications for users during movement: by foot, on ship, or by land vehicle. Uplink transmissions would be at 821-825Mhz and 14Ghz bands; downlink transmission could use the frequency bands at 866-870Mhz and at 12 Ghz. Advances dramatically increasing system capacity will be required.

2. INTERNATIONAL SATCOM SYSTEMS AND CONCEPTS

a. Current Systems

Although there are currently several regional SATCOM systems, INTELSAT and INMARSAT remain the dominant international SATCOM systems for the provision of fixed and mobile satellite communications, respectively.

(1) INTELSAT

The INTELSAT V series is the latest version of INTELSAT spacecraft. INTELSAT has satellites deployed over the three ocean regions: the Atlantic, the Pacific, and the Indian Ocean Regions(AOR,POR,IOR). Table 48 displays the typical characteristics of INTELSAT V.

The INTELSAT V design life is 7 years. Services provided by the INTELSAT system include: secure, high-quality voice; video conferencing; television; data and facsimile. A number of modulation and access methods exist to accommodate the various INTELSAT global services are in use, these are:

- Frequency division multiplex/frequency modulation(FDM/FM)
- Companded frequency division multiplex/frequency modulation(CFDM/FM)
- Preassigned single channel per carrier/quadrature phase shift keying (SCPC/QPSK)
- Demand assigned single channel pre carrier/quadrature phase shift keying

TABLE 48

SUMMARY OF THE INTELSAT V CHARACTERISTICS

Freq band	Number of Trans-ponders	Total effective BW(Mhz)	Transponder bandwidth (Mhz)	EIRP (dbw)
C-band	21	1362	77 72 36	23.5-29
Ku-band	6	780	77 72 241	41.1-44.4

- Single channel per carrier/companded frequency modulation for the VISTA service
- Frequency modulation television with associated audio FM-subcarrier(TV/FM) Time division multiple access with digital speech interpolation and without digital speech interpolation
- Digital transmission at intermediate data rates using QPSK/frequency division multiple access carriers(QPSK/FDMA) Digital transmission for INTELSAT business services using QPSK/FDMA

The INTELSAT V-A is an improved version of the basic INTELSAT V. Its performance specifications and characteristics are similar to INTELSAT V. Six additional transponders, however, are provided through frequency reuse, thus yielding a 25 percent increase in capacity.

The INTELSAT system uses several earth stations standards of varying complexity and capabilities. Typical earth station standards are in Table 49. The primary function of the first three standards(A,B and C) is to act as international gateways. The standard D earth stations are designed for the provision of thin route services; while recently introduced standards E and F earth stations are designed for the provision of International Business Services(IBS). INTELSAT has also established other earth station standards for international and domestic use(standards G and Z, respectively), which allow use of modulation and access methods, as well as earth station types other than those summarized above. These standards are intended for users with specialized requirements.

TABLE 49

TYPICAL EARTH STATION STANDARDS

Standard	Service	Freq band	G/T DB/°K	Antenna
A	International	C	40.7	30
B	International	C	31.7	11
C	International	KU	39	16
D-1	VISTA	C	22.7	5
D-2	VISTA	C	31.7	11
E-1	IBS	KU	25	3.5
E-2	IBS	KU	29	5.5
E-3	IBS	KU	34	8.0
F-1	IBS	C	22.7	4.5
F-2	IBS	C	27	7
F-3	IBS	C	29	9

(2) INMARSAT

The INMARSAT space segment consists of three types of satellites: MARISAT, MARECS, and INTELSAT V-MCS. The three MARISAT satellites leased from COMSAT General have been augmented by leased space segment capacity on two European space segment agency MARECS satellites and three INTELSAT-V satellites that incorporate a Maritime Communication Subsystem(MCS).

The INMARSAT system use both L and C-band frequencies as follows: ship to shore communications use L-band(1.6Ghz band) for uplink(ship to satellite) and C-band(4Ghz) for the downlink(satellite to shore). Shore to ship communications use C-band for uplink and L-band for downlink(satellite to ship). Typical INMARSAT space segment characteristics are summarized in Table 50.

The INMARSAT earth segment consists of two types of earth stations:

1. Coastal earth stations--These are owned and operated by INMARSAT signatories around the world. There are about a dozen such earth stations worldwide with several more being planned or under construction. These earth stations interface with international public switched networks. They are 10-13 meters in diameter(antenna) and are capable of up to 70dbw of EIRP per carrier.

2. Ship earth stations-- These earth stations are owned and operated by ship owners. Their average cost is about $30k; they incorporate autotrack equipment to enable the antenna beam to remain pointed at the satellite. The antenna diameter for these stations range from .9 to 1.2 meters.

TABLE 50

TYPICAL INMARSAT SPACE SEGMENT CHARACTERISTICS

characteristic	MARISAT	INTELSAT-V
C-to L-band repeater receive G/T, dbk L-band EIRP,dbw capacity, channel	 -19.6 27.0 12	 -12.1 33.0 35
L-to C-repeater receive G/T, dbk C-band EIRP,dbw capacity, channel	 -17 18.8 20	 -13 20.0 120

Service provided by the INMARSAT system include: telephone, telex, telegram, voice band data, facsimile and slow scan TV, 56kbps data transmission(ship to shore), 1Mbps data(ship to shore) using special ship earth stations, group call(broadcast) to ships of a particular fleet or national origin and to ships in a given geographical region, and distress and safety services.

b. **Mid-term(1986-1991) Systems**

INTELSAT and INMARSAT will continue to be the major international systems for the mid-term(1986-1991), although new generations of more advanced spacecraft will be introduced.

(1)INTELSAT

INTELSAT VI typifies mid-term commercial SATCOM technology. Development of this spacecraft is expected within 1986-1987. The INTELSAT VI space segment provides six times frequency reuse through polarization and spatial isolation. It also incorporates new technologies, such as satellite switched TDMA. Solid state power amplifiers are being used in addition TWTs. Typical INTELSAT VI characteristics are summarized in Table 51.

The INTELSAT VI spacecraft has a 10-year design life. It will provide two global, two hemispheric and four zone coverage at C-band, and two spot coverages at k_u-band. Table 52 illustrates summarizes the launch dates, the locations, and the

TABLE 51

INTELSAT VI TYPICAL CHARACTERISTICS

Freq band	Number of Transponders	Total effective BW(Mhz)	Transponder bandwidth (Mhz)	EIRP (dbw)
C-band	38	1367	36 72	23.5-31
Ku-band	10	780	72 241	41.1-44.4

coverages for the INTELSAT VI satellite. Increased demand for the various services is expected through the mid-term, particularly for International Business Services, (e.g., teleconferencing), which was recently introduced. This service is not normally intended to be used for public switched telephony. IBS services will be provided using standards A, B, C, E and/or F earth stations. Connectivity between these earth stations can be established using either C- or k_u-band transponders. The IBS digital carriers use QPSK modulation with FDMA, and carriers will be assigned fixed frequencies within a given transponder. Encoding, scrambling, and encryption may be employed.

TABLE 52

INTELSAT VI SUMMARY

Region	satellite location	service	time frame	coverage (ant)
AOR	325.5 335.5	primary	1991 1987	hemispheric zone, spot
IOR	60	primary	1988	hemispheric zone
POR	174	primary	--	hemispheric zone

(2) INMARSAT

Introduction of the second generation of INMARSAT satellites is expected in the late mid-term/early fer-term time frames. The new system enable INMARSAT to

expand the user population, support new earth station standards, and incorporate digital modulation and coding.

The future Global Maritime Distress and Safety System(FGMDSS) will integrate and corporate use of satellite and terrestrial radio links for improved distress and safety service including:

- Simple automatic distress alerting, mainly using Emergency Position Indicating Beacons(EIRPBs).
- Improved search and rescue communications
- Automatic on-board reception of distress messages as well as navigational and meteorological information for the ship's area of interest.

c. **Far-term(1992-2000) Systems**

The basic systems identified in previous section for the mid-term are expected to continue their services through the far-term.

(1) INTELSAT

The INTELSAT VI series of spacecraft and follow on is expected to continue to be the primary INTELSAT resource through the mid-to-late far-term. Beyond 1995, however, new generations of INTELSAT spacecraft, incorporating new technologies, may be introduced.

(2) INMARSAT

The third generation INMARSAT space segment envisioned for the mid-1990s is expected to incorporate spot beam coverages and L-band reuse. In addition, extended services for land mobile and aeronautical mobile users is under study. New digital earth station concepts are being studied and would incorporate:

- Lightweight, compact installations for message services on the order of 1 kbps
- Improved operation at low elevation angles
- Simple low power amplifier

The new station would cost about $6k. The message services are to include distress alerting, data graphics, image, and coded text. The new system will provide improved group call capabilities. This will allow broadcast messages, such as telex, facsimile, weather maps, and news broadcasts to be sent to specified areas and/or groups of ships

equipped with receive only terminals and to airborne systems featuring 400/600 bps for air traffic control, and 2.4-9.6 kbps voice and packet data. The antenna gains of these terminals are envisioned to be in the 8-12db range.

APPENDIX F
INTRODUCTION OF FIBER OPTIC TECHNOLOGY AND TRENDS

1. BACKGROUND

Telecommunications using signals at optical wavelengths offers the promise of extremely large communication capabilities. However, until recently, applications were limited by the absence of practical low attenuation transmission media and reliable light sources. The invention of the laser in 1958 rekindled interest in optical communications. The period of the 1960s saw considerable research in laser structures(the first semiconductor lasers reported in 1962) as well as extensive studies of both free space and guided wave propagation. In 1966, researchers in England predicted that glass fibers, if made sufficiently pure, might be useful for telecommunications. They predicted that fibers with attenuations of about 20 DB/Km might be achieved, and in 1970, first fibers having this attenuation were reported by Corning Glass Works. Also in 1970, the first semiconductor lasers to operate continuously at room temperature were reported by AT&T Bell Laboratories [Ref. 18: p. 24].

The first half of the 1970's was a period of extensive technology development. The first system experiments and trials began during 1976 and 1977, and first standard applications by telephone companies began during 1979 and 1980. Thus, it was less than 10years from the first indication in 1970 that this technology might be feasible until the beginning of practical transmission applications by telephone companies. This rather short time interval for the introduction of radically new technology.

The first half of the 1980's has been characterized by continued major advances in the technology and by a large expansion in applications. However, a review of technology trends is necessary to appreciate the evolving applications.

2. TECHNOLOGY

The three principal technology choices for fiber optic communication systems are: wavelength, short(800nanometers) or long(1300 - 1550nanometers); type of fiber,

multimode or single mode; and source, laser or light emitting diode(LED). [Ref. 18: p. 39].

a. Wavelength

The attenuation in glass fibers decreases with increasing wavelength until fundamental molecular absorption bands occur. Progress in reducing attenuation is illustrated in Figure E.1 [Ref. 20: p. 20].

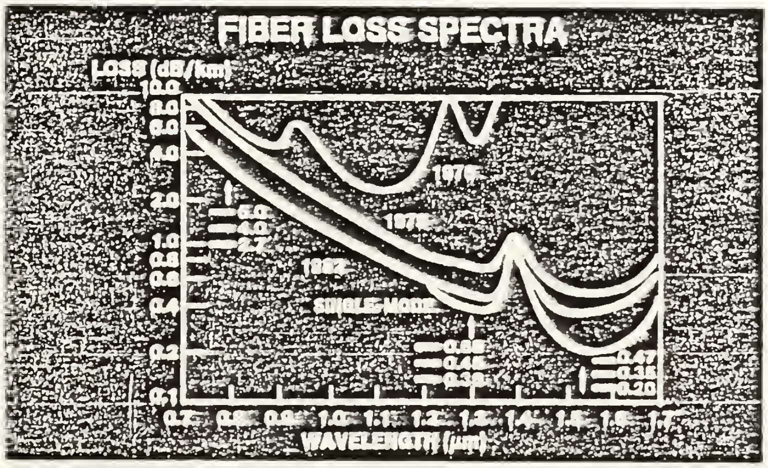

Figure E.1 Fiber Loss Spectra.

Although significant improvement have been made in lowering attenuation in the short wavelength region(800 - 900nanometers), the most significant improvements resulting from new composition fibers and much lower water content, is at the long wavelength(greater than 1000nanometers). Attenuations now achieved (0.35db/km at 1300nm and 0.2db/km at 1550nm) are essentially at the theoretical limits achievable with silica based glass.

b. Type of Fiber

Single mode fibers are no more difficult to manufacture--and hence not intrinsically more expensive--than low attenuation multimode fiber. However, owing to the smaller core diameter, it is more difficult to splice and connect such fibers. Considerable progress has been made in these areas today. Advances in the technology for manufacturing, connecting and splicing single mode fibers are leading to their increased application. A key advantage of single mode fibers is that they permit higher pulse

rates since there is no modal dispersion(different mode has different propagation delays). However, material dispersion results from the wavelength dependence of propagation delay. The 1300nm wavelength is of particular interest because not only is it a wavelength of low attenuation, but it is also the wavelength of minimum material dispersion in silica based glass.

c. **Sources**

Lasers couple more power into a fiber and are spectrally purer than LEDs. This results in a much higher bit rate and distance capability with lasers and single mode fibers than with LEDs and multimode fibers.

3. FIBER OPTIC ADVANTAGES

There are four areas in which fiber optics has important functional advantages: bandwidth, accuracy, security, and range.

a. **Bandwidth**

In strictly functional terms, the most appealing feature of fiber optics is its huge bandwidth. Current technologies for data transmission are continuously reported by AT&T Bell Laboratories, 4 billion bps over 60 miles. It will appear more billion bps over more miles in the near future. Although existing data communication technology cannot be use such capabilities fully on practical level, lab experiments demonstrate the tremendous potential of fiber optics as a medium for high-capacity data transmission. moreover, existing technology is able to exploit at least a significant part of the potential bandwidth of fiber optics. In some current applications, for instance, fiber optic cables handle data transmission at rates measured in tens or even hundreds of megabits. These rates should improve dramatically in the near future as new applications arise for data links with increasingly higher capacities [Ref. 21: p. 103].

b. **Accuracy**

Besides high capacity data transmissions, fiber optics also allows for extremely accurate transmissions. Currently, fiber optics has BER as low as one error per 10,000 billion bits over short distances. As low as this rate is by present standards, there should be continued improvement as the technology is refined. The high level of

accuracy that is possible with fiber optics is due largely to the considerable immunity properties inherent in the medium. Fiber optics is immune to electromagnetic and radio frequency interference, as well as interference from echoing and crosstalk. This immunity helps eliminate many of the data errors that often occur with other media. In addition to immunity, fiber optic cabling has a high degree of durability: it is nonflammable, tolerant of very high temperatures, and resistant to abrasion and to most corrosive substances. Such durability makes fiber optics well suited for use in a variety of harsh environments, many of which can affect adversely the integrity of data transmitted via other media.

c. Security

Some of the same properties that contribute to the accuracy of data transmitted over fiber optic cable also contribute to data security. For example, the immunity of fiber optics to certain types of interference is due partially to the fact that data signals are in the form of energy packets which have no electrical charge. As a result, fiber optics emits no radiation, electromagnetic pulses, or other energy that can be detected by other equipment. Security is enhanced additionally because it virtually is impossible to tab fiber optic cable without being detected - the signal loss resulting from tapping will be discovered almost immediately. Furthermore, it is possible to determine within a few inches where breaks in a fiber optic cable have occurred, which allows the location of any taps to be pinpointed readily on cable sections.

d. Range

Transmission range is another area in which fiber optics has an advantage over other area. Improved manufacturing processes have given fiber optics the ability to transmit light considerable distances with a minimal loss in intensity. Some fiber currently being made have so little dispersion that attenuation(signal loss) is only about 1DB per mile. Such low attenuation gives fiber optics a greater range between repeaters than any existing cables. This can eliminate or significantly reduce the number of repeaters needed on a communication link. Besides simplifying installation, few repeaters on a link reduces the number of locations at which data errors might be introduced during transmission.

4. SUBMARINE CABLE

In 1963 the cable ship operated by AT&T has laid 49,300 nautical miles of copper cable on ocean floors. Now that era has ended, and the ship is prepared for the age of optical fiber cables. The last coaxial cable installed by the ship was TAT-7(TAT: Trans-Atlantic Transmission), rated to carry up to 10,000 simultaneous two way conversations. The new lightwave link scheduled to begin service in 1988--TAT8--will handle four times as many conversations, and it's less than half the size of the copper cable.

For the TAT-8 system, the ship will install 3145 nautical miles of lightwave cable across the Atlantic to just beyond a branching repeater on the European continental shelf. On the other Ocean, the Hawaii4/Transpacific3 undersea cable system is scheduled to enter service on December 31,1988. Also a fiber optic system, the project will cost about $600 million. This system will include about 5064 nautical miles of optical fiber cable to be installed between California and Hawaii and then to a branching unit 2820 nautical miles from Hawaii. The Japanese company will install the branching unit and about 2077nm of fiber cable(852miles to Guam and 1245miles to Japan).

5. TRENDS

Fiber optics systems are displaying two key trends: first, transmission at higher bit rates with longer regenerator spacing; and second, increased levels of integration, both electronic and photonic. In recent experiments in AT&T Bell Laboratories, 420Mbps were transmitted without regenerators through 203Km of fiber. And 4Gbps were sent over 117Km of fiber without regenerators. Such increases in capacity and ungenerated distance are of particular interest for long distance transmission [Ref. 22: p. 33].

For short distances, increased integration and greater functionality are key to increased applications of fiber optics. Advances are being made in building multiple sources and detectors on the same semiconductor chip. AT&T also is progressing in obtaining combined optical and electronic functions in the same integrated circuits, such as combined detectors and preamplifiers. And signals in optical form are being given increased processing capability.

Fiber optic technology continues to be highly dynamic. The many applications to date are impressive demonstrations of the technology's potential. Even more dazzling may be the applications of the future, using bandwidth on demand to meet a wide range of customer needs for voice, data, and image services.

The overall capability for light wave systems has been doubling yearly, a trend that is expected to continue for the rest of the decade. AT&T demonstrated that a single glass fiber can handle--at 20 billion bps--ten ISDN signals, or the equivalent of 20 private lines, to each of 10 thousand users.

LIST OF REFERENCES

1. *Korean Affairs Report*, Foreign Broadcast Information Service, 3 July1986

2. Morley, English J., *Cost-Effectiveness*, John Wiley & Sons Inc, 1970

3. Hitch, Charles J.,and Roland McKean, *The Economics of Defense in the Nuclear Age*, Harvard University Press, Cambridge, Massachusetts, 1960

4. Life-Cycle Costing, TTO-ORT-032-78c-v3, *Cost-Effectiveness Program Plan for Joint Tactical Communications*, Vol 3, April1978

5. Gordon, Alfred M., *AIAA 11th Communication Satellite System Conference*, August1986

6. The Western Union Telegraph Co., *Satellite Provided Customer Premises Services*, Final report, Vol 3 Appendices, August1983

7. AFSC, LA AF Station, *Unmanned Space Craft Cost Model*, June1981

8. Gallawa, R.L., *Fiber and Integrated Optics*, Vol 3, number4, 1981

9. Christensen, M.M., Lustig, H.G., Stachyra, M.M., *System Analysis Criteria and Methodology for Electronic Systems*, Hughes Aircraft Company Ground Systems Group Fullerton,CA January1969

10. Joint Tactical Communications Office, Fort Monmouth NJ, *System Effectiveness*, November1974

11. Blanchard, Benjamin S., *Systems Engineering and Analysis*, Prentice-Hall Inc, 1981

12. Korean Electronics and Telecommunication Research Institute, "History and Future Telecommunication in the Republic of Korea," *Telecommunication Journal*, Vol 52 December1985

13. Pal, N.E., "An Approach to the Planning of International Telecommunication Networks," *Telecommunication Journal*, Vol 52 January1985

14. Staff Report, "The Present Condition and Forecasting of Fiber Optic Industry in Korea," *The Electronic Science (Published in Korean Language)*, Feburary1986

15. Hofacker, Richard Q. and Ira Jacobs, "The Wideband World of Fiber," *AT&T Bell Laboratory Record*, March1986

16. Au,Thomas p., *Engineering Economics for Capital Investment Analysis*, Allyn and Bacon Co, 1983

17. M/A-COM LINKABIT Inc, *Commercial SATCOM Subarchitecture Assessments and Intial Concepts*, Final report, November1985

18. Ira Jacobs, "Applications of Fiber Optic Communications," *Signal*, June1985

19. Nicholas Mokhoff, "Fiber Optics," *IEEE Spectrum*, January1982

20. Kanely, James R., "Fiber Optics in Telecommunications," *Telecommunication*, December1982

21. Robin Farmer, "Cost-Benefis of Fiber Optic Systems," *Telecommunication*, July1983

22. Lynch, John F., "Trends in Fiber Optics," *Signal*, June1985

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c.1 Cost effectiveness methodology for evaluating Korean international communication system alternatives.